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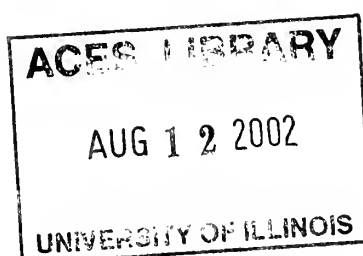
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Beef Research Report 1993



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THANK YOU

THE DEPARTMENT OF ANIMAL SCIENCES GRATEFULLY ACKNOWLEDGES THE ASSISTANCE OF THE FOLLOWING COMPANIES AND PEOPLE IN OUR BEEF PROGRAM:

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Zinpro, Edina, MN

THE DEPARTMENT OF ANIMAL SCIENCES
UNIVERSITY OF ILLINOIS

Dennis R. Champion, Head of Department

It is a pleasure to introduce the 1992 Beef Cattle Research Report. This past year has been a highly productive year, leading to many discoveries in the applied and basic areas. These discoveries are essential to fulfillment of our goal to enhance the profitability of beef cattle production.

The many successes enjoyed as a result of our research program requires the creativity and hands of many faculty, staff and students. Of special note in this regard is Kenneth Hewing, beef herder, who was recently recognized with a certificate and pin for 10 years of loyal and dedicated service to the University. Ken has been an exemplary and loyal employee. However, for health reasons, he was forced to go on disability this summer. All who have worked with Ken wish him the very best in the challenges he currently faces.

Several faculty involved in our beef program were again recognized for their professional activities. The College of Agriculture honored Dr. Dan Faulkner with the Young Faculty Award for Excellence in Extension and Dr. Larry Berger was the recipient of the American Feed Ingredient Association Award for Ruminant Nutrition presented by the American Society of Animal Science. Our congratulations to Dan and Larry for their well-deserved recognition.

Tom Nash became the Beef Unit manager at South Farms this past year. Previously, Tom managed the Sheep Unit at Dixon Springs Agricultural Center. Tom is continuing the tradition of excellent leadership at the Beef Unit.

In summary, the beef research program continues to excel as the result of the commitment and dedication of all involved in the program. We appreciate the opportunity to respond to the needs of our beef industry.

UNIVERSITY OF ILLINOIS PUREBRED ANGUS HERD

D. F. Parrett, D. B. Faulkner, T. G. Nash

The University of Illinois maintains 60 spring calving purebred Angus cattle. In addition, ten to fifteen replacement heifers are retained each year. The cattle are used in research and teaching. Teaching uses include: beef production, livestock judging and evaluation courses, and special learning classes for undergraduate student research projects. The students gain experience in performance record keeping, animal selection, hands-on laboratory experience, heat-detection, calving and general beef cow herd management.

Most of the research conducted using the cattle is related to applied nutrition and new management techniques. Recent work has concentrated on previous androgenization effects of beef calves, limited creep feeding, various estrous synchronization techniques for beef cows and gene mapping of purebred lines of cattle.

Many clinics, workshops, and judging activities also make use of the purebred cattle. The herd also serves as a catalyst for interaction between the Department of animal Sciences staff members and the Illinois purebred cattle industry. Performance tested bulls are sold each year through the Illinois Performance Tested Bull Sale. Bulls are also raised and used as herd sires for the commercial cow herds at the Dixon Springs and Orr Research Centers. By raising our own herd sires, we can provide predictable performance and uniformity in the cattle raised for research trials. Of particular importance is the development of a calving ease herd within the Angus herd. These cattle are bred specifically for low birth weight EPD's. This group will become an increasingly important segment of our targeted purebred production program. EPD's (expected progeny differences) are used extensively in designing the breeding programs, with a goal of optimum performance for our environment (table 1). Many breeders have supported our Angus program and we appreciate their efforts to enhance our program.

Cow Herd	Average EPD's				
	n	Birth	Weaning	Milk	Yearling
Calving Ease Herd	14	0.6	19	8	35
Performance Herd	32	4.5	30	9	47

1992 Angus A.I. Sires to Produce 1992 Calves

Sire	EPD's			
	Birth	Weaning	Milk	Yearling
• Hoff Hi Flyer	2.7	50	6	69
• TC Dividend	1.4	39	21	72
• Rito 9M9	5.6	39	16	60
• RR Travelor 5204	-1.5	24	18	44
• SVF Travelor 1130	-2.2	21	18	35

FACTORS INFLUENCING THE SALE PRICE OF BULLS

D. D. Buskirk and D. B. Faulkner

SUMMARY

One hundred thirty bulls (45 Angus and 85 Simmental) ranging in age from 10.7 to 24.4 mo were sold at the Performance Tested Bull Sale in Springfield, Illinois on February 20, 1992. The bulls had complete performance information, including: birth and weaning weights; birth, weaning and milk EPD, combination EPD ratio, scrotal circumference, frame (1-9 scale), sale day weight, weight per day of age, muscle (1-9 scale) and age. Bull buyers paid a premium for older, heavier bulls and those with above average combination EPD ratios. These traits account for a significant portion of the fluctuation in selling price. For the Simmental breed, there was also a preference for black and polled bulls. No other factors were important in developing prediction equations for the value of these bulls.

INTRODUCTION

Purebred bull breeders benefit from producing breeding stock desired by their purebred and commercial markets. To accomplish this, breeders need to identify the traits which are of greatest importance to their customers. Our objective was to measure the worth of several traits by identifying their influence on selling price in the 1992 Illinois Performance Tested Bull Sale.

PROCEDURE

One hundred thirty bulls (45 Angus and 85 Simmental) ranging in age from 10.7 to 24.4 mo were sold at the Performance Tested Bull Sale in Springfield, Illinois on February 20, 1992. As a prerequisite to sell, bulls must have been performance tested through their respective breed association testing program and meet minimum growth requirements.

Factors available for all bulls and used in the analysis included, birth and weaning weights; birth, weaning and milk EPD, combination EPD ratio $\{((-2.43 \times \text{BW EPD}) + (.75 \times \text{WW EPD}) + (.75 \times \text{MILK EPD})) - ((\text{breed average ratio})) + 100\}$ (Bryant and Lemenager, 1988), scrotal circumference, frame (1-9 scale (BIF, 1990)), sale day weight, weight per day of age, muscle (1-9 scale where 1=light muscling and 9 = heavy muscling based on two evaluators) and age. In addition, Simmental bulls had horn status, color and pattern recorded. Means, standard deviations and the range for these variables are given in Tables 1 and 2. These values and their squares were used as independent variables in stepwise multiple regression procedures (SAS, 1985) to develop the simplest equations that would adequately ($P < .05$) predict sale price. Simple correlations were calculated for all variables (SAS, 1985).

Color (black, brown, red or yellow), pattern (solid or spotted) and horn status (polled, scurred or horned) were utilized in the analysis of Simmental bulls. These factors could not be used in the prediction equations because they are all or none traits. All colors except black did not significantly ($P > .32$) effect sale price. Therefore, black was compared against all other colors combined. Horned and scurred bulls were also similar ($P = .91$) in sale price and combined for analysis. Pattern was a nonsignificant ($P = .60$) source of variation in sale price, therefore it was dropped from the analysis.

RESULTS

Sale prices averaged \$1,996 and \$1,729 for Angus and Simmental bulls, respectively. Angus bulls ranged from \$850 to \$3600 and Simmental ranged from \$900 to \$4900. Since many of the breeding programs producing bulls in this sale have put selection pressure on growth it is not surprising that the correlation between age and weight was high ($r^2=.83$). All other correlations of the traits of interest were relatively low.

Black Simmental bulls were worth \$564 more than other colors. Polled Simmental bulls were worth \$377 more than those horned or scurred. These factors were accounted for before the prediction equations were developed.

The prediction equations are shown below:

ANGUS

$$\text{Sale price} = -5665 + 848(\text{WDA}) + 38.30(\text{ratio}) + .00465(\text{age})^2$$

SIMMENTAL

$$\text{Sale price} = 255888 + .91(\text{weight}) - 538.45(\text{ratio}) + 2.88(\text{ratio})^2$$

These equations explain about 67% and 42% of the variation in sale price for Angus and Simmental bulls, respectively. These equations do not account for factors such as conformation, soundness, breeder reputation, fitting, etc. In addition, the Simmental equation does not include color and horn status which accounted for about 18% of the variation in price.

These multiple regression equations are difficult to evaluate, therefore we have graphed each factor individually while all other factors were input at their average value (see figures).

For Angus bulls, there was over a \$2000 spread in value due to age. The average age of these bulls was about 15 months. This roughly translates into \$5 per day of age. Weight may have been substituted into the equation since there was a high correlation between age and weight. There was a difference of about \$1000 due to combination EPD ratio, with each index point being worth \$38. There was a \$933 spread in value accounted for by gain lb/d (WDA). No other factors were important in developing the prediction equation for the value of these bulls.

For Simmental bulls, there was over a \$2000 spread in value due to the combination EPD ratio. There was a dramatic increase in price for bulls above the breed average (101.5). There was less than a \$200 discount for bulls below the average ratio, but up to a \$1900 advantage for those above. There was a \$1150 spread in value due to sale day weight. The average value per pound was \$.91 over the range of these bulls. Again, age may have been substituted into the equation due to the high correlation between weight and age. No other factors were important in developing the prediction equation.

Bull buyers paid a premium for older, heavier bulls and those with above average combination EPD ratios. These traits account for a significant portion of the fluctuation in selling price. For the Simmental breed, there is also a preference for black and polled bulls.

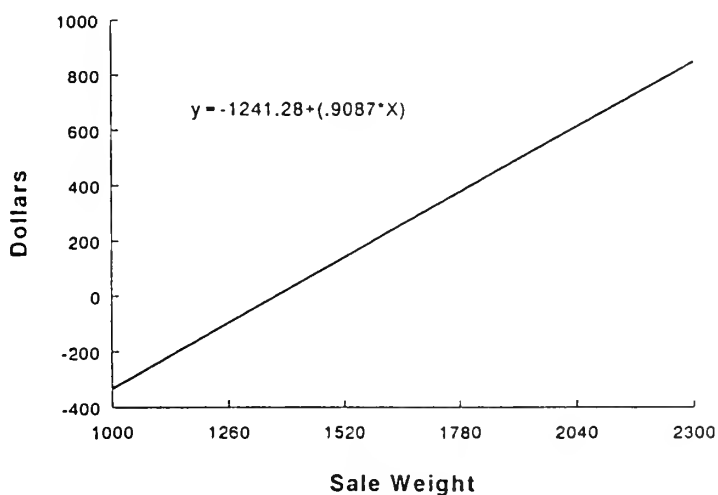
REFERENCES

BIF. 1990. Guidelines for Uniform Beef Improvement Programs. Beef Improvement Federation, Oklahoma State University, Stillwater, OK.

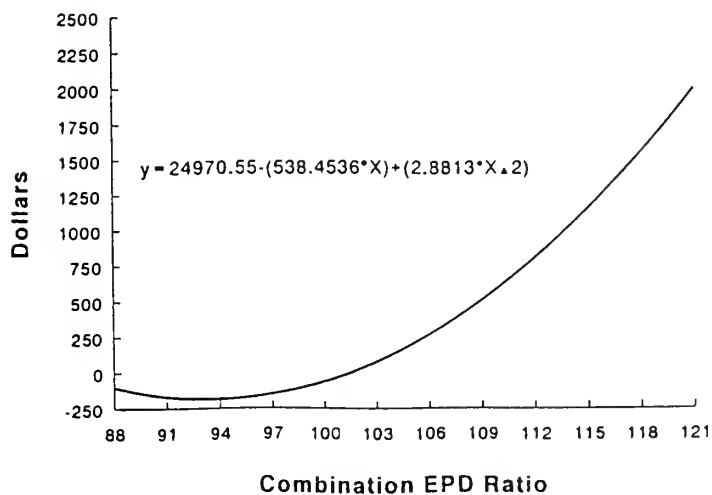
Bryant, D. E. and R. P. Lemenager. 1988. A computer program designed to assist producers in making bull selections and mating decisions. Beef Day Proceedings, Purdue University, September 2, 1988.

SAS. 1985. SAS User's Guide: Statistics. SAS Inst., Inc., Cary, NC.

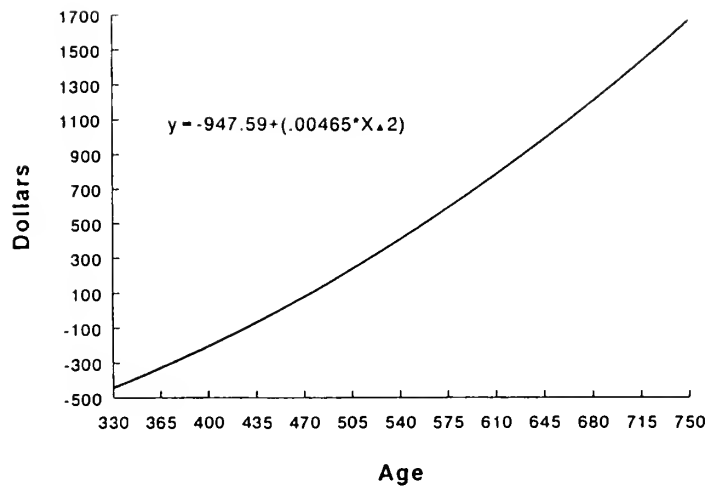
SIMMENTAL BULLS



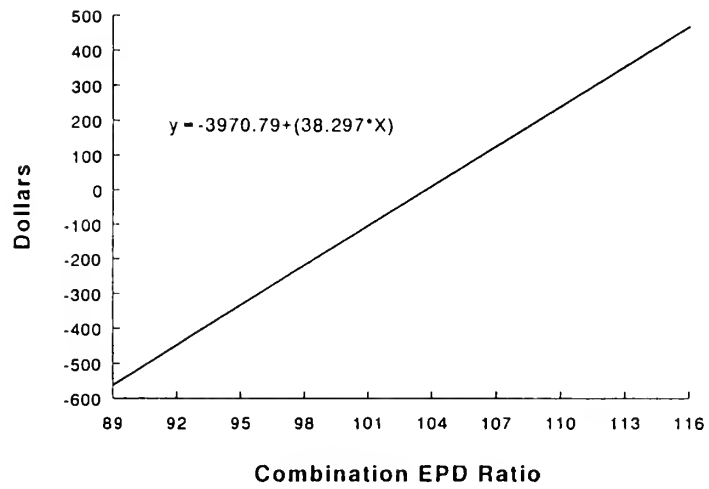
SIMMENTAL BULLS



ANGUS BULLS



ANGUS BULLS



ANGUS BULLS

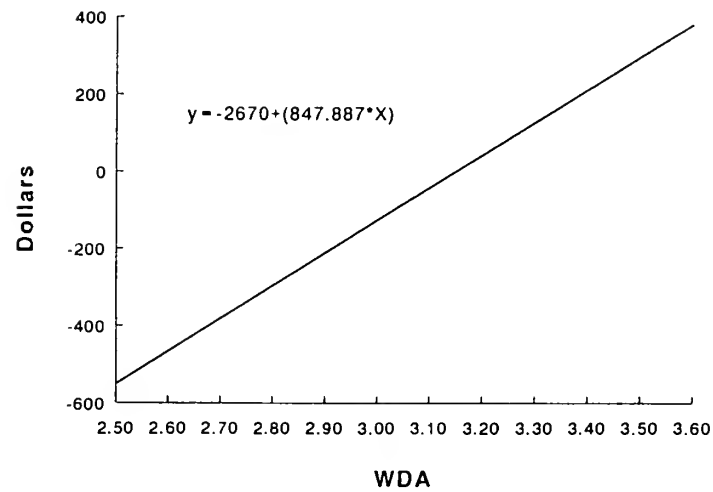


TABLE 1. STATISTICS FOR VARIABLES USED IN ANALYSIS

	Mean	Standard Deviation	Minimum Value	Maximum Value
Angus n=45				
Birth wt, lb	89.5	9.6	72.0	118.0
Weaning wt, lb	681.9	57.3	552.0	884.0
Birth EPD, lb	4.6	1.7	1.3	8.3
Weaning EPD, lb	30.0	7.1	10.0	45.0
Milk EPD, lb	10.0	4.5	0.0	23.0
Ratio	103.7	6.1	89.5	115.4
Frame ^a	7.0	.9	5.5	9.3
Weight, lb	1400	319	999	2288
Gain, lb/d	3.1	.3	2.5	3.6
Age, d	451	125	338	742
Muscle ^b	4.6	.7	3.5	6.5
Scrotal, cm	39.4	2.9	32.0	48.0
Simmental n=85				
Birth wt, lb	91.8	8.3	70.0	120.0
Weaning wt, lb	741.9	79.2	578.0	991.0
Birth EPD, lb	1.9	1.6	-2.0	5.0
Weaning EPD, lb	12.0	6.5	-4.0	25.0
Milk EPD, lb	-1.1	3.6	-11.0	7.0
Ratio	101.5	6.0	88.2	120.6
Frame ^a	8.1	.8	6.1	9.7
Weight, lb	1366	246	1025	2296
Gain, lb/d	3.3	.3	2.8	4.1
Age, d	415	82	326	704
Muscle ^b	5.4	.8	4.0	7.5
Scrotal, cm	38.8	2.8	31.0	48.5

^a1-9 scale according to Beef Improvement Federation 1990 Standards.

^b1-9 scale with 9 having the most muscling.

TABLE 2. SIMPLE CORRELATIONS FOR ANGUS BULLS

	Birth EPD	Weaning EPD	Milk EPD	Ratio	Frame	Weight, lb	Gain, lb/d	Age	Muscle
Weaning EPD, 1b	.57 ^a	.18							
Milk EPD, 1b	.01	.57 ^a	.70 ^a						
Ratio	-.17	.13	-.22	-.23					
Frame	.34 ^b	.13	-.05	-.23	.59 ^a				
Weight, 1b	-.02	-.25	.00	-.01	.06	-.34 ^b			
Gain, 1b/d	.18	.14	-.02	-.15	.46 ^a	.94 ^a	-.63 ^a		
Age, d	-.08	-.23	.05	-.00	-.06	-.09	.04	-.08	
Muscle	.02	-.02						.52 ^a	
Scrotal, cm	.03	-.28	-.22	-.39 ^a	.41 ^a	.61 ^a	-.06		-.27

^a(P < .01)
^b(P < .05)

TABLE 3. SIMPLE CORRELATIONS FOR SIMMENTAL BULLS

	Birth EPD	Weaning EPD	Milk EPD	Ratio	Frame	Weight, lb	Gain, lb/d	Age	Muscle
Weaning EPD, 1b	.26 ^b	-.24 ^b							
Milk EPD, 1b	-.24 ^b	.53 ^a	.43 ^a						
Ratio	-.56 ^a	.06	-.15	-.12					
Frame	.15	-.04	-.21	-.11	.44 ^a				
Weight, 1b	-.03	.19	.02	.03	.31 ^a	.08			
Gain, 1b/d	.20	-.11	-.20	-.11	.29 ^a	.91 ^a	-.32 ^a		
Age, d	-.12	-.08	.05	-.04	.01	.21 ^b	.16	.12	
Muscle	-.00							.54 ^a	
Scrotal, cm	-.12	-.13	-.17	-.11	.32 ^a	.62 ^a	.12		.05

^a(P < .01)
^b(P < .05)

THE EFFECT OF TIME ON CREEP FEED ON CALF AND COW PERFORMANCE

S.L.TARR, D.B.FAULKNER, F.A. IRELAND, D.D.BUSKIRK, AND D.F. PARRETT

SUMMARY:

Creep feeding calves for 56 or 84 days improved performance over control calves. The calves fed for 84 d gained more but tended to be less efficient in their gain than the calves fed 56 d. The cost of the supplemental feed and environmental conditions may determine how long calves should be supplemented. Calves supplemented for 28 d showed no advantage in daily gain over the controls thereby utilizing the supplemental feed quite inefficiently. Therefore, this is not a desirable option if fall regrowth of cool season pastures is occurring. Increasing the length of time on creep decreased the feed efficiency of feedlot gain, but had no effect on carcass characteristics.

INTRODUCTION:

Many cattlemen have problems with low pasture productivity and slow calf gains during midsummer. It is a common practice to supplement nursing beef calves on pasture. This practice is known as creep feeding. It is well documented that calves fed ad libitum creep feed gain faster, compared to non creep fed calves, but have a relatively poor feed efficiency. Recent research has shown that limiting creep intake may improve supplemental feed efficiency while increasing calf gains. An alternative to limiting intake may be to limit the time on creep feed to improve feed efficiency. Therefore, the objective of this experiment was to evaluate the effect of time on creep on calf and cow performance.

PROCEDURE:

Eighty four (84) Angus x Hereford crossbred cows nursing steer calves were utilized in a creep feeding study. The calves weighed approximately 152 kg at the beginning of the trial which was conducted from July 16 through October 8, 1990. Steers were randomly assigned to 3 replicates, to receive one of 4 lengths of creep feeding (0 d, 28 d, 56 d, or 84 d). Cows with steer calves (7) were kept in each of twelve tall fescue pastures (8 acres). Calves receiving creep feed were confined with a creep feeder during the first day exposed to creep feed (Table 1). A small amount of dried molasses was scattered on top of the exposed feed to stimulate consumption. Calves receiving creep had ad libitum access to creep feed for their respective times. All individual calf and cow weights were taken after a 16 hour withdrawal from water and group creep intake was obtained at 28 d intervals from day 0 to day 84 of the study.

Calves were weaned and placed on a finishing ration (Table 2) for 225 days. Body weights at the beginning and end of the finishing period and feed intakes were recorded to calculate daily gain and gain/feed.

At the conclusion of the finishing period calves were slaughtered. Carcass parameters recorded were hot carcass weight, adjusted fat thickness, marbling score, rib eye area, internal fat, and quality grade. Yield grades were also calculated.

Statistical analysis were conducted using GLM procedure of SAS. Performance and carcass data were analyzed using pen as the experimental unit. Treatment mean differences were separated using F-test for least significant difference.

RESULTS:

Time on creep had a large influence on calf performance but did not influence cow performance (Table 3). Calf daily gain was .49 kg/d more for the 84 d creep treatment compared to the control. The 56 d treatment showed a .24 kg/d response in gain, but no response was observed for the 28 d treatment. The 84 d treatment calves were taller ($P<.05$) and tended to be fatter ($P=.07$) than the control calves, but the differences were small (.11 cm in fat and 1.7 cm in height). Supplemental feed efficiency was best for the 56 and 84 d treatments, while the 28 d treatment was extremely poor (.02 gain/feed). The second period of the experiment was hot and dry (Figure 1). It began raining about the start of period 3 so fall regrowth of grass was plentiful. This may explain some of the observed intake differences.

In the feedlot control calves had increased gain, however no difference was observed between the other treatments (Table 4). The 84 d and control treatments had slightly higher intakes. The control calves tended to be more efficient ($P=.07$) during the finishing period, with other treatments showing no response. Increasing the length of time on creep had no influence on characteristics. (Table 5).

FIGURE 1.

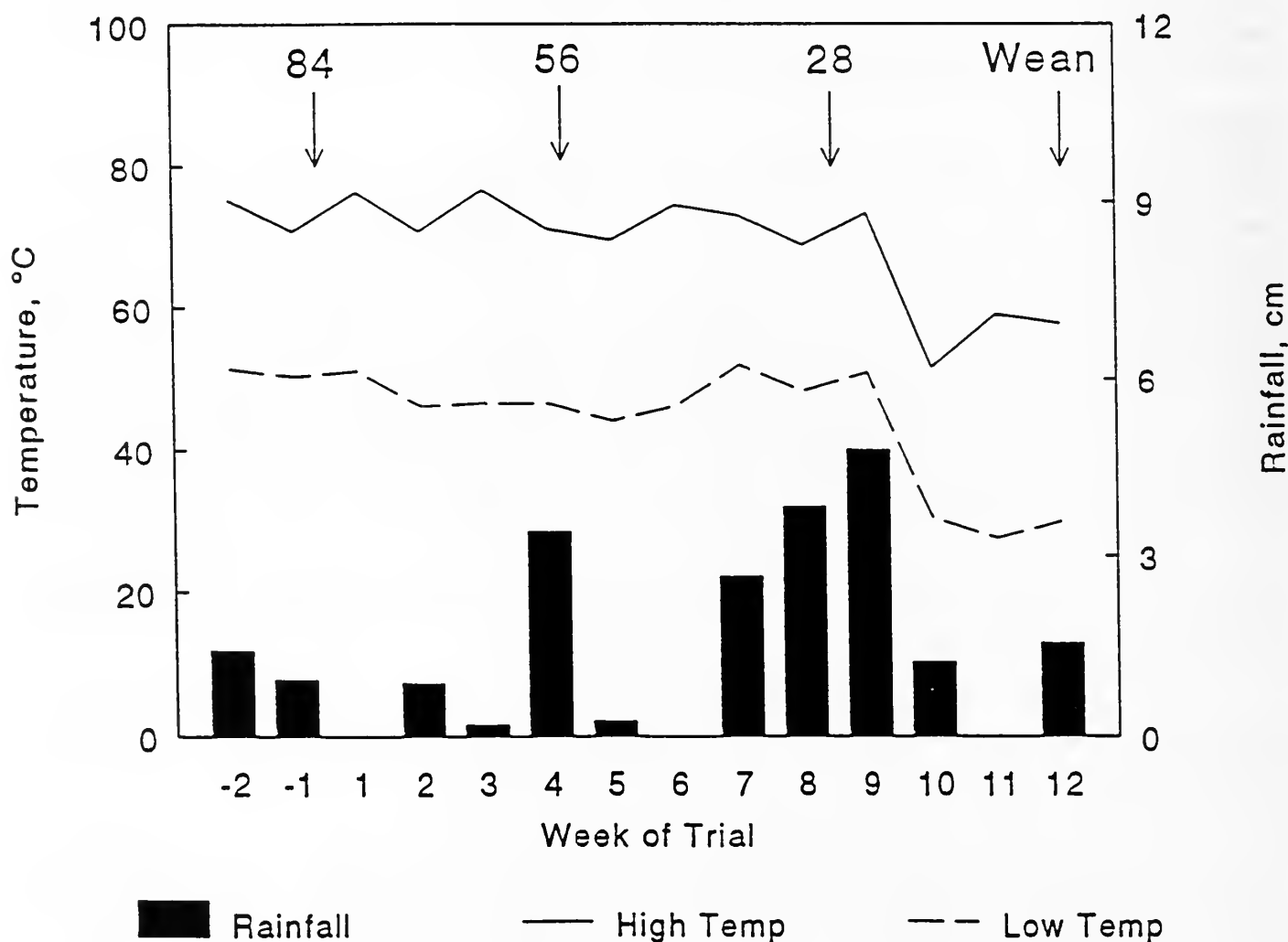


TABLE 1. Chemical composition of creep feed¹

Dietary component	% Dry Matter Basis
Organic Matter	90.5
Crude Protein	14.9
NDF	48.5
ADF	16.6

TABLE 2. Ingredient composition of finishing diet fed to steers

Ingredients	% Dry Matter Basis
Corn	84.0
Chopped hay	10.0
Soybean meal	3.75
Urea	.25
Limestone	1.00
Dicalcium phosphate	.50
Salt	.50
Vitamin Premix	+

¹Creep feed supplied by Central Soya, Decatur, IN

TABLE 3. Growth, creep intake, and feed efficiency of steer calves and weight and body condition change of their dams as influenced by length of time receiving supplemental creep feed.

Item	DAYS RECEIVING CREEP				SEM
	0	28	56	84	
<u>Dam</u>					
Initial wt, kg	441.3	444.4	445.0	446.5	6.8
Wt change, kg	-20.6	-18.6	-16.2	-22.7	2.7
Final CS ^a	3.8	3.8	4.1	4.0	.3
<u>Calf</u>					
Initial wt, kg	156.6 ^b	152.6 ^{bc}	151.8 ^{bc}	146.9 ^c	2.1
Weight gain, kg/d					
period 1	.89 ^b	1.01 ^{bc}	.99 ^{bc}	1.14 ^c	.06
period 2	.14 ^b	.25 ^b	.55 ^c	.95 ^d	.07
period 3	.52 ^b	.59 ^{bc}	.82 ^{cd}	1.07 ^d	.08
overall	.52 ^b	.62 ^b	.79 ^c	1.05 ^d	.04
Creep intake, kg/d					
period 1	-	-	-	4.8	
period 2	-	-	2.0 ^e	4.8 ^f	.3
period 3	-	2.1	1.7	1.8	.3
overall	-	2.1 ^b	1.9 ^b	3.8 ^c	.4
Supplemental G/F					
period 1	-	-	-	.05	
period 2	-	-	.23	.17	.07
period 3	-	.02 ^b	.17 ^c	.30 ^d	.03
overall	-	.02 ^b	.19 ^c	.14 ^c	.02
Final Backfat, cm	.61	.68	.70	.74	.05
Final hip height, cm	107.2 ^b	107.5 ^{bc}	107.2 ^b	109.3 ^c	.58

^aCS = Body condition score (1-9 scale)

^{bcd}Least squares means in the same row with different superscripts differ (P < .05).

^{efg}Least squares means in the same row with different superscripts differ (P < .01).

TABLE 4. LENGTH OF CREEP FEED ON SUBSEQUENT PERFORMANCE DURING FINISHING PERIOD

Item	Days on Creep				SE
	0	28	56	84	
Gain, Kg/day ^{ab}	1.40	1.25	1.25	1.25	.031
Intake, Kg/day ^a	8.4	7.9	7.7	8.2	.117
Gain/feed	.17	.16	.16	.15	.005

^aQuadratic effect (P<.05).

^bLinear effect (P<.05).

TABLE 5. LENGTH OF CREEP ON CARCASS CHARACTERISTICS

Item	Days on Creep				SE
	0	28	56	84	
Rib eye area, cm.	28.9	28.2	28.3	28.4	.40
Fat thickness, cm.	1.18	1.05	1.06	1.20	.072
Yield grade	2.98	2.83	2.90	3.05	.127
Quality grade ^a	10.7	10.4	10.4	10.6	.253

^a10=Low Choice; 11=Average Choice.

CHANGING BREEDING SEASON TO IMPROVE REPRODUCTIVE PERFORMANCE OF COWS GRAZING ENDOPHYTE INFECTED TALL FESCUE

D. B. Faulkner, D. D. Buskirk, J. W. Castree, and G. F. Cmarik

SUMMARY

Crossbred (Hereford x Angus) beef cows were bred in early and late spring for 63 days. The cows grazed tall fescue from April 15 until December 15. From December 15 to April 15 the cows received 5 lb/head/day of corn silage and mature fescue hay ad libitum. Objectives of the study were to evaluate the influence of breeding season on reproductive performance and calf performance for cows grazing tall fescue. The pregnancy rate was improved for the early breeding season. No differences were observed if calf weaning weights were adjusted to a common age; however, if the calves were weaned at the same time, the early breeding season calves were heavier because they were older. Breeding cows on fescue in the spring appears to improve conception rate compared to summer breeding.

INTRODUCTION

Tall fescue, grown on over 35 million acres, is the most widely spread pasture grass in humid areas of the eastern USA and, to a limited extent, in the northwestern USA (Buckner et al., 1979). A fungal endophyte Acremonium coenophialum has been associated with fescue toxicosis in cattle. In a review, Studeman and Hoveland (1988) concluded that high levels of endophyte reduced steer performance and inferred, based on limited data, that a reduction in weaning weight, cow milk production, cow weight gain or loss and reproductive efficiency would be expected on endophyte infected fescue. Tucker et al. (1989) observed a decrease percentage of cows pregnant on high compared to low endophyte infected fescue with spring calving cows. This was probably due to the high nutrient requirements for cows between calving and breeding combined with declining fescue quality and the effects of the endophyte.

The effect of the endophyte seems to be increased by high relative temperature (Hannah et al., 1990). Crawford et al. (1989) observed a decrease in performance as endophyte level increased during the summer, but found no effect during the fall when environmental temperatures were cooler. The objectives of this study were to determine the effect of breeding season on reproductive performances of beef cows and the performance of their calves while grazing endophyte infected tall fescue.

MATERIALS AND METHODS

Spring calving Hereford x Angus crossbred cows, ranging in age from 2 to 11 yr, were assigned to two breeding seasons based on calving time. In the first year, the early breeding season started April 18 and the late season May 23 and in the second year the dates were April 11 and May 23, respectively. All the breeding seasons were 63 days in length. The number of observations for a particular variable varied due to open cows, death losses, and culling for unsoundness. The range was from 343 observations for pregnancy rate to 236 for calving interval.

The cows were managed as one group from the end of breeding to calving. At calving time the cows and calves were split into two breeding herds for each breeding season (4 herds total). The cows were synchronized using the recommended procedure for Synchro-mate-B and artificially inseminated (AI) on day 1 of the breeding season. On day 3 of the season bulls were placed with the cows for the remaining 60 days of the season. The cows were AI and exposed to either Angus or Hereford bulls based on their sire breed. The sire breed used was the opposite of the sire breed of the cow (two breed rotational system). The bulls were rotated within sire breed to reduce sire effects.

The four breeding herds were grazed on endophyte infected (greater than 95% infestation) fescue from April 15 until the end of the late breeding season. These groups were rotated among pastures to reduce pasture effects. After breeding the cows were managed as a single group on fescue until December 15. From December 15 to April 15 the cows were fed ad libitum mature fescue hay (harvested from the same pastures) and 5 lb/head/day of corn silage (dry matter basis). A mineral-vitamin-trace mineral salt mixture was available to the cows at all times (Table 1).

The calving date and birth weight were recorded for each calf. The calves were weaned and the weaning weight recorded when the average age of the late group of calves was 204 days. The cows were rectally palpated at this time and all open cows were sold. In addition, any cow with a structural problem, cancer eye, a bad udder or over 11 years old was sold.

Sources of variation tested in the analysis of variance of reproductive performance included years (two), breed groups (two), sex of calf (two), and breeding season (two), and their interactions. Cow age was used as a covariant in the analysis. In addition, chi square analysis was utilized to evaluate pregnancy rate (Cochran and Cox, 1957). Calf birth and weaning weights were analyzed in the same manner and with calf age as an additional covariant.

RESULTS AND DISCUSSION

There were no interactions, year effects, calf sex effects or breed group effects observed ($P>.17$) on reproductive performance; therefore, only the main effects of breeding season are presented. The pregnancy rate of the cows was improved ($P<.05$) for the early breeding season compared to the late breeding season (Table 2). The pregnancy rate for the late breeding season (77 percent) is similar to other studies with spring calving cows grazing endophyte infected tall fescue (Tucker et al., 1989). The improved pregnancy rate for the early breeding season group (86 percent) might be due to reduced heat stress during the breeding season. Work with stocker cattle has demonstrated that the endophytic fungus decreases performance during midsummer grazing, but no effect is observed during fall grazing (Crawford et al., 1989). It has been established that the effects of the endophytic fungus are more pronounced at high temperatures (Hannah et al., 1990).

The calving interval was shorter ($P<.001$) for the late breeding season group than for the early season group and was 13 days less than a year (Table 2). This shorter calving interval when combined with the reduced pregnancy rate suggests that the cows bred during the first part of the late breeding season when the combined effects of temperature and endophyte were less pronounced. From these

results, it appears that cows can be bred in April, May and June to avoid the fescue problem.

Calf performance was also influenced by breeding season (Table 2). The early group averaged 48 days older ($P<.01$) and 35 lb heavier at weaning ($P<.01$) than the late group if they were adjusted for age. If the weaning weights were adjusted for age there were no difference between the two breeding seasons. Birth weight was heavier ($P<.01$) for the early group than for the late group. This response may be due to late gestation nutritional difference (hay and corn silage compared to fescue pasture). Bellows and Short (1978) observed differences in birth weight due to nutrition during gestation.

CONCLUSIONS

Breeding cows in April, May and June may help to avoid the fescue problem resulting in improved reproductive performance. Leaving these earlier born calves on the cow would result in increased weaning weights due to increased age. However, if the calves are weaned at a given age no differences in weaning weight would be expected between the two breeding season we compared.

REFERENCES

- Bellows, R. A. and R. E. Short. 1978. Effect of precalving feed level on birth weight, calving difficulty and subsequent fertility. J. Anim. Sci. 46:1522-1528.
- Buckner, R. C., J. B. Powell, and R. V. Frakes. 1979. Historical development. In R. C. Buckner and L. P. Bush (ed.) Anti-quality components of forages. Spec. Pub. 4. CSSA, Madison, WI.
- Cochran, W. G. and G. M. Cox. Experimental Designs 2nd ed. Publ. John Wiley and Sons, New York 1957.
- Crawford, R. J., Jr., J. R. Forwood, R. L. Belyea, and G. B. Gardner. 1989. Relationship between level of endophyte infection and cattle gains on tall fescue. J. Prod. Agric. 2:147-151.
- Hannah, S. M., J. A. Patterson, J. E. Williams, M. S. Kerby, and J. L. Miner. 1990. Effects of increasing dietary levels of endophyte-infected tall fescue seed on diet digestibility and ruminal kinetics in sheep. J. Anim. Sci. 1693-1701.
- Stricker, J. A., A. G. Matches, G. B. Thompson, V. E. Jacobs, F. A. Martz, H. N. Wheaton, H. D. Currence, and G. F. Krause. 1979. Cow-calf production on tall fescue-ladino clover pasture, with and without nitrogen fertilization or creep feeding: Spring calves. J. Anim. Sci. 48:13-25.
- Stuedemann, J. A. and C. S. Hoveland. 1988. Fescue endophyte: History and impact on Animal Agriculture. J. Prod. Agric. 1:39-44.
- Tucker, C. A., R. E. Morrow, J. R. Gerrish, C. J. Nelson, G. B. Gardner, V. E. Jacobs, W. G. Hires, J. J. Shinkle, and J. R. Forwood. 1989. Forage systems for beef cattle: Effect of winter supplementation and forage system on reproductive performance of cows. J. Prod. Agric. 2:217-221.

Table 1. Nutrient Composition of Mineral Supplement^a

	<u>%</u>
Salt	41.0
Ca	11.7
P	9.1
Mn	.11
Cu	.10
Fe	1.42
Zn	1.15
I	.005
Se	.0043

^aAlso contained 80,000 IU/lb. vit. A and 4,000 IU/lb vit. E

Table 2. Reproduction of Cows Grazing Tall Fescue with
Different Breeding Seasons

	Breeding Season		SE
	Early	Late	
Pregnancy Rate, % ^e	86 ^a	77 ^b	3
Calving Interval, d ^f	370 ^c	352 ^d	4

^{ab} Values in a row not having a common superscript differ (P<.05).

^{cd} Values in a row not having a common superscript differ (P<.001).

^e 343 observations

^f 236 observations

Table 3. Calf Performance on Fescue due to Breeding Season

	<u>Breeding Season</u>		SE
	Early	Late	
Age at weaning, d	252 ^a	204 ^b	3
Birth Weight ^d , lb.	84.7 ^a	74.6 ^b	2.3
Adjusted Weaning Weight ^d , lb.	407	422	14
Weaning Weight ^{cd} , lb.	435 ^a	405 ^b	13

^{ab} Values in a row not having a common superscript differ ($P < .01$).

^c Not adjusted for age of calf

^d 318 observations

LINKAGE RELATIONSHIPS BETWEEN BOVINE FGR, FUCA1, ALPL, PGD AND THE B AND C BLOOD GROUP LOCI

J. E. Beever, D. F. Parrett, D. B. Faulkner, H. C. Hines and H. A. Lewin

ABSTRACT

Our goal is to develop a comparative linkage map in cattle for genes which reside on human chromosome 1. Comparative gene maps comprised of structural gene loci will provide necessary information for studying chromosomal evolution and for use in marker-assisted selection programs. Linkage relationships between the bovine Gardner-Rasheed feline sarcoma viral oncogene homolog (FGR), fucosidase (alpha-L-1-, tissue; FUCA1), alkaline phosphatase (liver/bone/kidney; ALPL), phosphogluconate dehydrogenase (PGD) and the B and C red blood group loci were investigated. Restriction fragment length polymorphisms (RFLP) have been identified for each locus with the restriction enzymes *RsaI* (FGR), *TaqI* (FUCA1 and ALPL) and *MspI* (PGD). RFLPs for each locus were scored for five sires, 187 half-sib offspring and their dams. Multilocus linkage analysis was performed using LINKAGE (version 5.10). For the bovine genes FGR, FUCA1 and ALPL, the order and genetic distances were found to be consistent with their human homologs. The recombination fractions (θ) for the most likely order FGR-FUCA1-ALPL were $\theta = 0.074$ and $\theta = 0.048$ ($z = 17.23$), respectively. Lod scores do not support PGD, RBC-B or -C as being members of this linkage group. Since PGD was used as an anchor locus for bovine synteny group U1, we cannot yet determine whether FGR, FUCA1 and ALPL are part of U1. Furthermore, based on the tight linkage of FGR and FUCA1 to the human RH blood group locus, we conclude that neither of the highly polymorphic bovine RBC-B and -C systems is likely to be the RH homolog.

INTRODUCTION

Development of genetic maps in our agriculturally important species is currently a fundamental goal in the field of animal research. To generate a genetic map in cattle we have chosen a method based on the conservation of synteny among species. By using information from highly developed genetic maps of other species, like humans and mice, we can examine the genetic relationships of homologous genes in cattle. We have chosen to generate a comparative map of loci located on human chromosome 1 (HSA1) for two reasons. First, we previously reported associations between the bovine B blood group and several quantitative traits in a large paternal half-sib family of beef cattle (Beever *et al.*, 1990). It was our hypothesis that the B blood group may be the homolog of the human RH blood group; both blood groups are highly polymorphic, each having multiple antigenic determinants that are inherited as allelic characters. Secondly, there appears to be substantial syntenic conservation among loci on HSA1 and bovine U1 (Heuertz and Hors-Cayla, 1981; Womack and Moll, 1986; Womack *et al.*, 1989). Therefore we have chosen several genes that are in close proximity to the RH blood group in man for comparative linkage analysis. These include the Gardner-Rasheed feline sarcoma viral oncogene homolog (FGR), fucosidase (alpha-L-1-, tissue; FUCA1), alkaline phosphatase (liver/bone/kidney; ALPL), and phosphogluconate dehydrogenase (PGD) which was selected as an anchor locus for bovine synteny group U1. The objective of this study was to identify restriction fragment length polymorphisms (RFLPs) for these loci and to examine their linkage relationships with the B and C blood group loci.

MATERIALS AND METHODS

Animals. Animals used in this study included the offspring and dams from five paternal half-sib families. Families ranged in size from 15 to 60 offspring. The animals were both purebred and crossbred Angus, Red Angus, Simmental, Salers, Gelbvieh and South Devon.

RFLP Analysis. Genomic DNA was isolated from leukocytes or semen according to Miller *et al.* 1988 or Andersson *et al.* 1986, respectively. Ten micrograms of DNA was digested using 50 units of the appropriate restriction enzyme under conditions recommended by the supplier for a 200 μ l reaction volume (Gibco BRL, Gaithersburg, MD). Digested DNA was subsequently precipitated and resuspended in 10 μ l of 1X loading buffer. Electrophoresis was performed in 1% agarose gels for 6-20 hrs at 60-35 V. The DNA was capillary transferred to nylon membranes (Biodyne B; Pall Biosupport Company, Glen Cove, NY) using 0.4M NaOH for 3-6 hrs. Membranes were prehybridized and hybridized as described by Beever and Lewin (1992a).

Red Blood Cell Typing. Red blood cell typing was performed at The Ohio State University Cattle Blood Typing Laboratory (Columbus, OH).

Linkage Analyses. Data were analyzed for linkage between loci using the MLINK (two-locus) and ILINK (multilocus) programs contained in LINKAGE (version 5.10).

RESULTS AND DISCUSSION

Linkage was found between the loci FGR, FUCA1 and ALPL (Table 1). The most likely order (odds ratio = 1.4:1) for these loci was FGR-FUCA1-ALPL (Table 2). Linkage of the PGD, B and C loci to the previously mentioned genes or between themselves was not supported by these data (Table 1).

From these data it is apparent that the genetic linkage and order of FGR, FUCA1 and ALPL is conserved in cattle, analogous to the HSA1 and MMU4 gene maps (Figure 1; O'Brien and Marshall-Graves, 1991). However, contrary to HSA1 and MMU4, these loci are separated from PGD which is located on bovine synteny group U1 (Womack and Moll, 1986). This result is further supported by somatic cell hybrid mapping of FGR and FUCA1 to bovine U17 (Fries, 1992). Genetic distances between these genes and their HSA1 homologs are also relatively conserved. For humans, genetic distances for males of $\theta = 0.00$ and $\theta = 0.016$ are reported between the pairs of loci FGR-FUCA1 and FUCA1-ALPL, respectively (Dracopoli *et al.*, 1988). In humans the RH blood group is tightly linked to FGR, FUCA1 and ALPL. Therefore, our results indicate that neither of the highly polymorphic B and C blood groups is likely to be the RH homolog. However, the possibility remains that the bovine RH homolog has been separated from this linkage group during chromosomal evolution, in which case it may be located on bovine U6.

CONCLUSIONS

1. FGR, FUCA1 and ALPL are not genetically linked to PGD, suggesting that these genes are not located on bovine synteny group U1.
2. FGR, FUCA1 and ALPL define a new bovine linkage group.

3. The gene order and genetic distances between bovine FGR, FUCA1 and ALPL are relatively conserved as compared to the HSA1 gene map.
4. Neither of the highly polymorphic bovine B and C blood groups are likely to be homologs of the human RH blood group.

IMPLICATIONS

One basic limitation of applying biotechnology to animal agriculture is our limited knowledge of the number and chromosomal location of genes that influence quantitative traits. Comparative mapping is a powerful method to develop genetic maps of type I anchor loci in our agricultural species. By using this method we may be able to quickly locate genes of physiologic interest, candidate genes, in cattle and evaluate their effects on economically important traits.

REFERENCES

- Andersson, L., Böhme, J., Rask, L. and Peterson, P. A. (1986) Genomic hybridization of bovine class II major histocompatibility genes: 1. Extensive polymorphism of DQ α and DQB genes. *Animal Genetics* 17, 95-112.
- Beever, J. E., George, P. D., Fernando, R. L., Stormont, C. J., and Lewin, H. A. (1990) Associations between genetic markers and growth and carcass traits in a paternal half-sib family of Angus cattle. *Journal of Animal Science* 68, 337-344.
- Beever, J. E. and Lewin H. A. (1992a) Restriction fragment length polymorphism at the bovine liver, bone and kidney alkaline phosphatase (ALPL) locus. *Animal Genetics* 23, (in press).
- Dracopoli, N. C., Stanger, B. Z., Ito, C. Y., Call, K. M., Lincoln, S. E., Lander, E. S. and Housman, D. E. (1988) A genetic linkage map of 27 loci from PND to FY on the short arm of human chromosome 1. *American Journal of Human Genetics* 43, 462-70.
- Fries, R. (1992) The bovine gene map.
- Heuertz S. and Hors-Cayla, M. C. (1981) Cattle gene mapping by somatic cell hybridization; study of 17 enzyme markers. *Cytogenetics and Cell Genetics* 30, 137-45.
- Miller, S. A., Dykes, D. D., and Polesky, H. F. (1988) A simple salting out procedure for extracting DNA from human nucleated cells. *Nucleic Acids Research* 16, 1215.
- O'Brien, S. J., and Marshall-Graves, J. A. (1991) Report of the committee on comparative mapping. *Cytogenetics and Cell Genetics* 58, 1124-1151.
- Womack, J. E. and Moll, Y. D. (1986) Gene map of the cow: conservation of linkage with mouse and human. *The Journal of Heredity* 77: 2-7.
- Womack, J. E., Threadgill, D. W., Moll, Y. D., Faber, L. K., Foreman, M. N., Dietz, A. B., Tobin, T. B., Skow, L. C., Zneimer, S. M., Gallagher, D. S. and Roger, D. S. (1989) Syntenic mapping of 37 loci in cattle: chromosomal conservation with mouse and man. *Cytogenetics and Cell Genetics* 51, 1109.

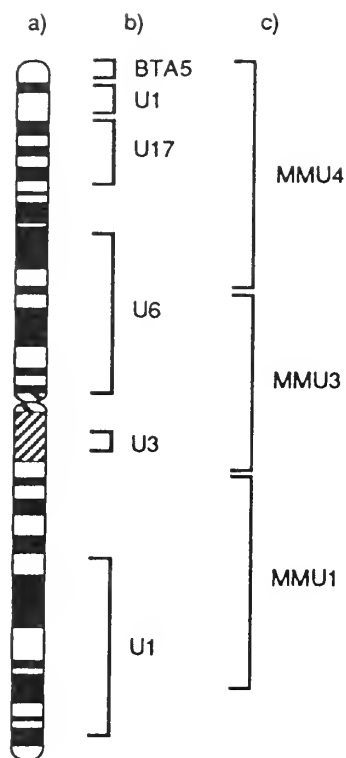


Figure 1.

a) human chromosome 1 (HSA1).
b, c) areas within each bracket indicate conservation of synteny between HSA1 and the bovine or mouse gene map, respectively; the prefix U designates a syntenic group which has not been assigned to a specific bovine chromosome.

Table 1.

LOD scores for pair-wise analysis of linkage

Loci	n	Recombination Fraction (θ)						z_{\max}	θ
		0.01	0.05	0.10	0.15	0.20	0.50		
FGR-FUCA1	56	3.41	3.78	3.65	3.37	2.99	0.00	3.78	0.052
FUCA1-ALPL	56	5.37	5.61	5.31	4.84	4.29	0.00	5.63	0.038
FGR-ALPL	131	6.54	10.53	11.25	10.91	10.07	0.00	11.25	0.102
ALPL-PGD	60	-25.72	-13.11	-7.74	-4.80	-2.93	0.00	0.00	0.532
FGR-B	187	-66.51	-32.65	-19.07	-11.86	-7.32	0.00	0.00	0.500
FGR-C	187	-68.05	-33.43	-19.47	-12.01	-7.30	0.00	0.03	0.549
PGD-B	60	-19.38	-9.59	-5.51	-3.29	-1.89	0.00	0.00	0.505
PGD-C	60	-26.83	-14.21	-8.87	-5.88	-3.91	0.00	0.00	0.505

Table 2.

Most likely orders based on multipoint linkage analysis

Possible order	Log-likelihood	z	θ_1	θ_2
FGR-FUCA1-ALPL	-251.8843	17.23	0.074	0.048
FGR-ALPL-FUCA1	-252.0233	17.09	0.107	0.039
ALPL-FGR-FUCA1	-252.5032	16.62	0.099	0.046

EFFECTS OF ZINC PROTEINATE ON HOOF DURABILITY IN FEEDLOT HEIFERS

B. A. Reiling, L. L. Berger, G. L. Riskowski, R. E. Rompala, and T. G. Nash

SUMMARY

Zinc has been shown to be essential for the keratinization of epithelial tissues. It has been postulated that trace minerals complexed to organic compounds may enhance absorption compared to inorganic trace minerals. The purpose of this study was to evaluate the effects of ZnSO₄ and Zn proteinate supplements on hoof strength of feedlot heifers. Sixteen yearling and 32 two-year old open heifers were fed 180 mg supplemental Zn per head daily as either Zn proteinate or ZnSO₄ for 45, 60, or 75 d. Upon slaughter, front hooves from each animal were collected. The bottom of each toe was planed, and a cross-sectional 5 mm thick slice obtained for shear analysis. An MTS material testing machine was utilized to measure the force required to shear a 1.3 cm diameter hole through the bottom side of the hoof slice. The GLM procedure of SAS was used to analyze the 2 X 2 factorial design. Hoof thickness was used as a covariate. Variables analyzed included maximum force required, slope of elastic deformation, and slope of permanent deformation. Hooves from heifers fed Zn proteinate showed a trend ($P < .16$) to require greater force for shearing, demanding 3.62% (198.3 kg) greater force than ZnSO₄ (191.4 kg). These hooves also appeared to exhibit greater elasticity ($P < .10$) compared to controls. Age of heifer significantly affected maximum force required and elasticity ($P < .05$). Interactions were not significant. Time exposed to supplementation was significant ($P < .05$) as cattle fed 75 d required 206.2±6.0 kg force compared to 181.7±4.1 kg for those fed 45 d to shear a 5-mm thick slice. Results indicate supplemental Zn proteinate may enhance hoof strength.

INTRODUCTION

Foot rot is a major cause of lameness in beef and dairy cattle. *Fusobacterium necrophorum* and *Bacteroides melaninogenicus* are the predominant bacterial species which act synergistically (Berg and Loan, 1975) to produce this infectious disease. However, a port of entry must be present for initiation of the disease to occur.

Zinc, an essential trace mineral, is necessary for the keratinization or proper hardening of epithelial tissues (Mills et al., 1967). Improperly keratinized tissues of the hoof could crack and provide a port of entry for the infectious agents of foot rot. In addition, serum Zn levels decline during activation of the immune response (Klasing, 1988). Thus, Zn supplementation should effectively aid in the prevention of foot rot through maintenance of healthy hooves and a competent immune system.

However, traditional supplementation of Zn as either ZnSO₄ or Zn oxide, has produced inconsistent results. Demertzis and Mills (1973) orally administered foot rot infected cattle with either 4.5 or 7.0 mg ZnSO₄·7H₂O per kg liveweight and found the additional Zn to potentially promote antibody production and acceleration of tissue repair. Cross and Parker (1981) also found ZnSO₄ to be beneficial in the prevention of new infections when sheep were housed under dry conditions, however, ZnSO₄ was of no benefit under wet conditions. Similarly, Egerton et al. (1985) found neither low (1-8.6 mg Zn/kg) nor high (65-82 mg Zn/kg) oral Zn therapy to reduce *B. nodosus* infections.

One reason for this inconsistency may be that Zn oxide is not well utilized by ruminants. Sources such as Zn methionine have a greater bioavailability (Heinrichs and Conrad, 1983). Moore et al. (1989) found dairy cattle fed 200 mg/hd/d supplemental Zn methionine exhibited greater epithelial integrity, a slightly harder hoof, and fewer incidences of foot rot compared to controls fed no supplemental zinc.

Thus, the objective of this trial was to compare the effectiveness of supplemental ZnSO₄ and Zn proteinate for the enhancement of hoof strength as a potential deterrent of foot rot.

MATERIALS AND METHODS

Sixteen yearling and 32 two-year old open heifers were randomly assigned to one of two zinc supplementation treatments in a 2 X 2 factorial design (two ages and two types of zinc supplementation). These heifers were fed an 85% concentrate diet supplemented with 180 mg zinc per head per day as either ZnSO₄ or Zn proteinate for a period of 45, 60, or 75 d in order to

obtain an average subcutaneous fat thickness of 1.0 cm at time of processing. The cattle were housed in confinement on solid concrete floors which were cleaned approximately every two weeks throughout the trial. The trial was conducted during the months of November, 1991, through January, 1992.

Upon slaughter, front hooves from each animal were collected and stored at 0° C until subsequent analyses were performed. The bottom of each toe (2 toes per hoof) was planed, and a cross-sectional 5 mm (.2 in) thick slice obtained for shear analysis. An MTS material testing machine was outfitted with a shear apparatus to measure the force required to shear a 1.3 cm (.5 in) diameter hole through the bottom side of the hoof. Prior to shearing, hooves were measured with a micrometer to obtain actual thickness which was used as a covariate for all statistical analyses.

Data collected included maximum force required for penetration, slope of elastic deformation, and slope of permanent deformation (Figure 1). The slope of elastic deformation, for which no physical damage has yet occurred, was determined as the force required per mm thickness through 2 mm of compression. The slope of permanent deformation was determined as the force required per mm thickness for actual shearing of the sample.

A protected F-test as determined by the GLM procedure of SAS (1988) was used to assess differences in treatment means of the 2 X 2 factorial design. Interactions were not significant and deleted from the final model.

RESULTS AND DISCUSSION

The effects of zinc supplementation type upon indices of hoof strength are shown in Table 1. Hooves from heifers fed Zn proteinate required 3.62% greater ($P < .16$) total force for shearing than hooves from heifers fed ZnSO_4 . In closer evaluation of the shear curve (Figure 1), Zn proteinate increased ($P < .06$) the quantity of force absorbed (elastic deformation) before actual shearing was initiated indicating greater strength. Once initiated, differences in the slope of permanent deformation were not significant.

Hooves of two-year old heifers were stronger than that of yearling heifers

(Table 2). Again, increases in maximum force required were the primary result of an increase in the force absorbed prior to initiation of permanent damage. Results shown in Tables 1 and 2 would indicate that greater hoof strength allows for greater absorption of force prior to actual shearing of the material.

Table 3 shows the effects of length of zinc supplementation upon indices of hoof strength. Cattle fed 180 mg/hd/d supplemental zinc for more than 60 d produced hooves that required greater ($P < .05$) total force for shearing compared to those fed only 45 d. Thus, it would appear that for increased strength and integrity for the potential prevention of foot rot, greater lengths of supplementation time will provide more desirable results.

IMPLICATIONS

180 mg/hd/d of supplemental Zn proteinate appears to enhance ($P < .16$) overall strength of hooves collected from feedlot heifers fed for a period of 45 to 75 d. It also appears that a greater length of time for supplementation (75 vs 45 d) may increase hoof strength and integrity even more. Certainly, more study is needed to more closely evaluate the potential usefulness of supplementing Zn proteinate for the prevention of foot rot.

LITERATURE CITED

- Berg, J. N. and R. W. Loan. 1975. *Fusobacterium necrophorum* and *Bacteroides melaninogenicus* as etiologic agents of foot rot in cattle. *Am. J. Vet. Res.* 36:1115.
- Cross, R. F. and C. F. Parker. 1981. Oral administration of zinc sulfate for control of ovine foot rot. *J. Am. Vet. Med. Assoc.* 178:704.
- Demertzis, P. N. and C. F. Mills. 1973. Oral zinc therapy in the control of infectious pododermatitis in young bulls. *Vet. Rec.* 93:219.
- Egerton, J. R., E. A. Laing, and R. C. Mulley. 1985. Failure of oral zinc therapy to alleviate *Bacteroides nodosus* infections in cattle and sheep. *Aust. Vet. J.* 62:85.

- Heinrichs, A. J. and H. R. Conrad. 1983. Rumen solubility and breakdown of metal protein compounds. J. Dairy Sci. 66(Suppl 1):4 (Abstr.).
- Klasing, K. C. 1988. Nutritional aspects of leukocytic cytokines. J. Nutr. 118:1436.
- Mills, C. F., A. C. Dalgarno, R. B. Williams, and J. Quarterman. 1967. Zinc deficiency and the zinc requirements of calves and lambs. Br. J. Nutr. 21:751.
- Moore, C. L., P. M. Walker, J. R. Winter, M. A. Jones, and J. W. Webb. 1989. Zinc methionine supplementation for dairy cows. Transactions of the Illinois Academy of Science. 82:99.
- SAS. 1988. SAS User's Guide: Statistics. SAS Inst., Inc., Cary, NC.

FIGURE 1. DIAGRAM OF FORCE REQUIRED TO SHEAR A 5 mm THICK
HOOF SLICE

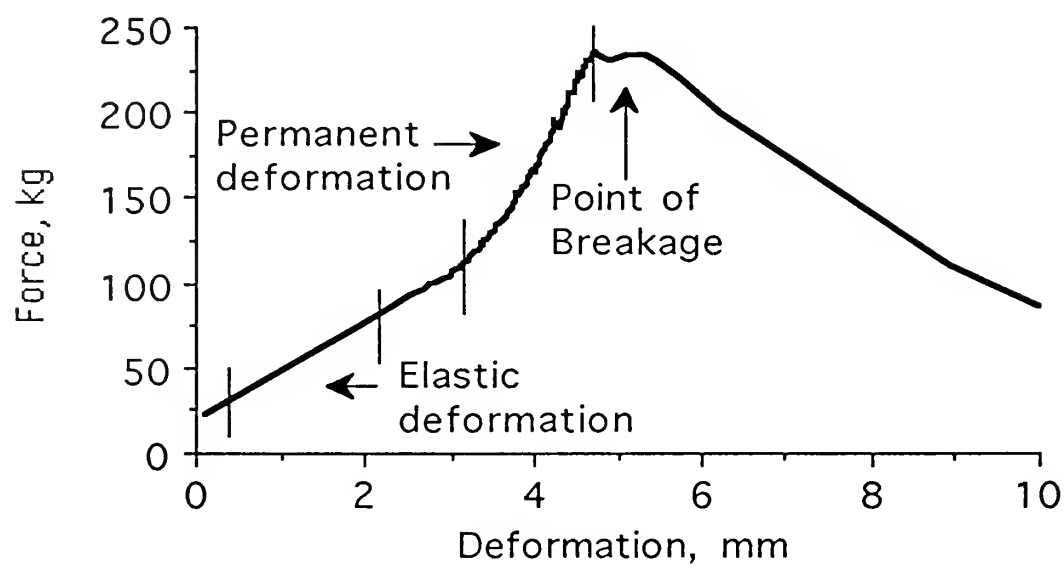


TABLE 1. EFFECTS OF ZINC SUPPLEMENTATION UPON INDICES OF
HOOF STRENGTH

Item	ZnSO ₄	Zinc Proteinates	SEM ^a	Treatment Effect ^b
Number	24	24		
Maximum force, kg	191.4	198.3	3.6	.1524
Elastic deformation				
kg force / mm thickness	22.75	24.68	.75	.0593
Permanent deformation				
kg force / mm thickness	49.75	52.74	2.33	.3388

^aLargest SEM of treatment means reported.

^bProbability of observing a greater F-value.

TABLE 2. EFFECTS OF AGE UPON INDICES OF HOOF STRENGTH

Item	Yearlings	Two-year olds	SEMa	Treatment Effect ^b
Number	16	32		
Maximum force, kg	189.2	200.5	4.2	.0261
Elastic deformation				
kg force / mm thickness	22.43	25.00	.87	.0165
Permanent deformation				
kg force / mm thickness	50.02	52.47	2.72	.4464

^aLargest SEM of treatment means reported.

^bProbability of observing a greater F-value.

TABLE 3. EFFECTS OF LENGTH OF ZINC SUPPLEMENTATION UPON INDICES OF HOOF STRENGTH

Item	45 d	60 d	75 d	SEMa	Treatment Effect ^b
Number	14	27	7		
Maximum force, kg	181.7 ^c	196.6 ^d	206.2 ^d	6.0	.0034
Elastic deformation					
kg force / mm thickness	23.07	22.99	25.09	1.26	.3024
Permanent deformation					
kg force / mm thickness	46.24	51.52	55.98	3.91	.1151

^aLargest SEM of treatment means reported.

^bProbability of observing a greater F-value.

^{cd}Means that do not have common superscripts differ ($P < .05$).

THE EFFECTS OF ROASTING TEMPERATURE ON SITE OF PROTEIN DIGESTION BY STEERS FED WHOLE SOYBEANS.

C. G. Aldrich and N. R. Merchen

SUMMARY

A 4 X 5 Youden square design was used to determine the effect of roasting temperature of whole soybeans on escape of N from the rumen and disappearance of N from the small intestine in steers. Four steers (average weight 822 lb) cannulated at the rumen, duodenum, and ileum were fed each treatment diet (1.8% BW) over five periods. The basal diet contained corn silage (50% of diet dry matter), alfalfa hay (24%), corn:urea premix (6%), corn starch grits (16.6%) and soybean oil (3.4%). Soybeans (16% of diet dry matter), either raw or heated to an exit temperature of 285°, 300°, or 315°F in a commercial roaster, replaced the soybean oil and most of the corn starch grits in the soybean treatment diets. Ruminant, small intestinal, and total tract digestibility of organic matter were not affected ($P > .05$) by treatment. Nitrogen intake was greater ($P < .05$) for diets containing whole soybeans and total N reaching the duodenum was greater ($P < .05$) for soybean diets. Non-bacterial N (dietary N) and apparent total tract N digestibility were increased ($P < .05$) by feeding soybeans. Soybean N reaching the duodenum decreased with increased roasting temperature. However, disappearance of soybean N in the small intestine as a proportion of the soybean N entering the small intestine increased with increased roasting temperature. Total, essential, and nonessential amino acid flows to the duodenum increased ($P < .05$) when soybeans were fed. Roasting temperature of 300°F maximized the flow of amino acids to the small intestine. Ruminant ammonia N was greatest ($P < .05$) for whole soybeans roasted at 315°F, and lowest for the basal diet. Increased roasting temperature of whole soybeans appear to make soybeans more brittle and subsequently more degradable in the rumen. However, the quantity of N available in the small intestine of steers was increased due to increased digestibility of soybean N that reached the small intestine.

INTRODUCTION

Whole full fat soybeans are a readily available source of protein for cattle in the midwest. Improvement in the utilization of soybean protein has been demonstrated when the whole seed is roasted. Feeding roasted soybeans has improved average daily gain of lambs, and increased milk production and milk protein in dairy cows (Faldet, 1989). Stern et al. (1985) reported that extruding soybeans at 300°F decreased protein degradation in the rumen, increased total flow of amino acids to the small intestine, and increased amino acid disappearance from the small intestine. Thus, heating has the effect of increasing the protein escape from the rumen for whole soybeans, and increasing the supply of amino acids to the animal. However, little information is available on the level of heating necessary to maximize these responses. Therefore, it was our objective to determine the effect of roasting temperature of whole soybeans on the site of organic matter and N (protein) digestion and the flow of amino acids to the small intestine in steers.

PROCEDURES

Four Angus x Simmental crossbred steers (average weight 822 lb) cannulated at the rumen, proximal duodenum, and terminal ileum were fed whole soybean supplemented diets in a 4 x 5 Youden square (incomplete latin square) designed experiment (Cochran and Cox, 1957). Each steer was fed the five treatment diets over the course of 5 periods.

The basal diet consisted of corn silage (50% of diet dry matter), alfalfa hay (24%), corn-urea premix (6 %), corn starch grits (16.6%) and soybean oil (3.4 %; Table 1). Urea was added to insure that N would not limit microbial growth. Soybean oil was included at an amount equivalent to that provided by the soybeans in the soybean containing diets. Soybeans (16% of diet dry matter), either raw or heated to an exit temperature of 285°, 300°, or 315°F in a commercial roaster (Vita Plus Corporation; Madison, WI), replaced all of the soybean oil and most of the corn starch grits in the soybean containing diets. Complete diets were mixed daily, and fed in 12 equal portions at 2 hour intervals by an automatic feeder. Dry matter intake was restricted to 15 lb/hd/d (1.8% of body weight), and water was available continuously. Chromic oxide (15 g chromic oxide/d) was fed as an external marker to measure digesta flow and fecal output. Steers were housed in individual pens in a temperature-controlled (22°C) room under continuous lighting.

Experimental periods were 13 d long with 9 d of diet adaptation and 4 d of sample collection. Duodenal and ileal fluid (300 mL) samples were collected 6 x daily at 4 h intervals, composited by steer, and freeze dried. Feces were collected 3 x daily, composited by steer, and dried at 55°C. Ruminal contents were collected at four 30-h intervals. Ruminal fluid pH was measured immediately and samples (50 ml) were acidified with 5 ml 6 N HCl and frozen for later determination of $\text{NH}_3\text{-N}$ and VFA. In addition, a bacteria-rich fraction was isolated from whole ruminal contents.

Dried and ground (1 mm) feed ingredients, duodenal and ileal digesta, feces and the bacterial-rich fraction were analyzed for DM, OM, and Kjeldahl-N. Chromium content of duodenal, ileal, and fecal samples was determined by atomic absorption spectrophotometry. Amino acids in duodenal, ileal, and bacterial samples, composite samples of soybean treatments, and the basal diet were measured following hydrolysis with 6 N HCl. Duodenal and bacterial samples were analyzed for purine content to determine the flow of bacterial N to the duodenum.

RESULTS

Dry matter intake was restricted to 1.8 % of body weight. Thus, organic matter intake was similar among treatments (Table 2). Organic matter digestibility in the stomach, small intestine and total tract were not affected by treatment.

Nitrogen intake was greater ($P < .05$) for diets containing soybeans and total N reaching the duodenum was greater ($P < .05$) for soybean diets, but roasting did not significantly increase total N flow (Table 3). Bacterial N flow at the duodenum was not affected by diet. The flow of non-bacterial N (dietary N) to the duodenum was increased ($P < .05$) by supplementation with soybeans. Although not significant, the greatest flow of non-bacterial nitrogen was achieved when soybeans roasted at 285° F were fed with a slight decline at the 300° and 315° F roasting temperatures. Apparent total tract N digestibility was increased ($P < .05$) for the soybean- containing diets. This observation is primarily a function of N intake rather than an attribute of the soybeans or roasting. Disappearance of N (g/d) in the small intestine was not affected ($P > .05$) by treatment.

Duodenal soybean N flow was calculated by subtracting the non-bacterial N flow at the duodenum for the basal diet from the non-bacterial N flow at the duodenum for the soybean containing diets (Table 4). Soybean N reaching the duodenum was greater for the roasted soybeans than for

raw soybeans. Similar to non-bacterial N, soybean N flow at the duodenum for soybeans roasted at 300° and 315°F was lower than for soybeans roasted at 285°F. Ruminal soybean N disappearance was calculated by subtracting duodenal soybean N from intake of soybean N. Ruminal soybean N disappearance (g/d) was decreased due to roasting. Soybeans roasted at 300° or 315°F were more brittle (personal observation) than soybeans fed raw or roasted to 285°F and subsequently may be more susceptible to degradation in the rumen. Tice et al. (1991) demonstrated that protein in ground roasted soybeans had a lower ruminal escape value than roasted soybeans fed either cracked or whole. The disappearance of soybean N in the small intestine was increased from 3.6 to an average of 22 g/d for the raw vs roasted soybean treatments, respectively. The quantity of soybean N disappearing from the small intestine was unaffected by roasting temperature yet, the quantity of soybean N reaching the small intestine was decreased by increasing roasting temperature. This was possible because soybean N disappearing from the small intestine as a proportion of that entering increased with roasting temperature. Thus, increasing roasting temperature improved small intestine digestibility of soybean N. This observation would implicate a role for heating soybeans for ruminants similar to that for non-ruminants. Namely, that heating deactivates the trypsin inhibitor activity in soybeans, and improves their utilization.

Flows of the essential amino acids (EAA) threonine, valine, isoleucine, leucine, phenylalanine, histidine, lysine and total EAA were increased ($P<.05$) by addition of soybeans to the diet (Table 5). Roasting increased ($P<.05$) the flows of threonine, valine, leucine, phenylalanine, histidine, and total EAA to the duodenum. Flows of the non-essential amino acids (NEAA) aspartate, serine, glutamate, proline, alanine, tyrosine, and total NEAA were increased ($P<.05$) by addition of soybeans. Roasting increased ($P<.05$) the flows of aspartate, serine, alanine, and total NEAA. Total amino acid flow to the small intestine was increased ($P<.05$) by the addition of soybeans to the diet. In addition, roasting increased ($P<.05$) total amino acid flow to the small intestine with maximum flows observed when soybeans roasted at 300°F were fed.

Ruminal ammonia concentration was lowest ($P<.05$) for the basal diet (Table 6). Molar proportions of acetate and propionate in ruminal fluid were not affected by treatment. However, the molar ratio of butyrate was decreased ($P<.05$) by the 300° and 315°F heat treatment in relation to the other soybean-containing diets. The molar proportion for isobutyrate and valerate, although having a significant F statistic ($P<.05$), do not appear to

be biologically different. Isovalerate molar proportion and total VFA concentration were not different among treatments.

CONCLUSION

Addition of soybeans to the basal diet increased the flow of N to the small intestine. More specifically, roasting soybeans appears to decrease ruminal degradation of soybean protein. However, soybean N flow to the small intestine decreased when soybeans were roasted at temperatures greater than 285°F. This response to increased roasting temperature may be due to a change in physical resilience of the soybeans; as roasting temperature increased, the brittleness of the soybeans increased. However, the quantity of N available to steers was increased due to increased digestibility of soybean N that reached the small intestine.

LITERATURE CITED

- Cochran, W. G., and G. M. Cox. 1957. Experimental Designs. John Wiley and Sons, New York.
- Faldet, M. A. 1989. Heat treating soybeans to maximize protein utilization by ruminants. Ph.D. Thesis. University of Wisconsin.
- Stern, M. D., K. A. Santos, and L. D. Satter. 1985. Protein degradation in rumen and amino acid absorption in small intestine of lactating dairy cattle fed heat-treated whole soybeans. J. Dairy Sci. 68:45.
- Tice, E. M., M. L. Eastridge, and J. L. Firkins. 1991. Feeding whole raw vs. roasted soybeans of different particle sizes to lactating cows. J. Dairy Sci. 74(Supp. 1):251 (Abstract).

TABLE 1. INGREDIENT COMPOSITION AND NUTRIENT PROFILE (% DRY MATTER BASIS) OF EXPERIMENTAL DIETS.

Ingredient	Basal	Raw	285°F	300°F	315°F
Corn silage	50.0	50.0	50.0	50.0	50.0
Alfalfa hay	24.0	24.0	24.0	24.0	24.0
Corn:Urea premix ^a	6.0	6.0	6.0	6.0	6.0
Soybean treatment					
Raw	--.-	16.0	--.-	--.-	--.-
285°F	--.-	--.-	16.0	--.-	--.-
300°F	--.-	--.-	--.-	16.0	--.-
315°F	--.-	--.-	--.-	--.-	16.0
Cornstarch grits	16.6	4.0	4.0	4.0	4.0
Soybean oil	3.4	--.-	--.-	--.-	--.-
<u>Nutrient profile:</u>					
DM, %	52.0	51.7	52.1	52.1	52.5
OM, %	94.9	94.1	94.3	94.2	94.1
N, %	1.7	2.7	2.7	2.7	2.7
CP, %	10.6	16.8	16.9	16.9	16.9
ADF, %	24.5	25.0	25.0	24.5	25.0
NDF, %	38.3	39.3	40.3	39.2	40.0

^aThe corn:urea premix contained ground corn (67.5%), vitamin premix (1.67%), trace mineralized salt (4.17%), dicalcium phosphate (10.0%) and urea (16.67%).

TABLE 2. ORGANIC MATTER INTAKE AND DIGESTION OF WHOLE ROASTED SOYBEAN SUPPLEMENTED DIETS IN STEERS (LS MEANS).

item	Basal	Raw	285°F	300°F	315°F	SE
OM intake, g/d	6433	6369	6397	6397	6406	5.8
Duodenal OM, g/d	3196	3225	3273	3392	3091	154.7
OM apparently digested in stomach, g/d	3237	3144	3124	3005	3315	153.6
% OM intake	50.3	49.4	48.8	47.0	51.8	2.40
OM truly digested in stomach, g/d	4239	4242	3964	4054	4322	209.6
% OM intake	65.9	66.6	61.9	63.4	67.5	3.26
OM digested in small intestine, g/d	1168	970	1103	1437	1205	204.3
% OM intake	18.1	15.2	17.3	22.4	18.8	3.18
Apparent total tract OM digestibility, %	71.9	72.0	72.4	72.7	71.9	.35

TABLE 3. NITROGEN INTAKE AND DIGESTION OF WHOLE SOYBEAN SUPPLEMENTED DIETS FED TO STEERS.

Item	Basal	Raw	285°F	300°F	315°F	SE
N intake, g/d	116.0 ^a	180.9 ^b	183.3 ^c	183.4 ^c	184.4 ^d	.24
Duodenal N, g/d						
Total	116.4 ^a	138.2 ^b	150.3 ^b	151.0 ^b	145.1 ^b	4.61
Bacterial	73.1	74.0	70.6	76.8	74.6	4.36
Nonbacterial	43.3 ^a	64.2 ^b	79.7 ^b	75.2 ^b	70.5 ^b	5.66
Apparent total tract N digestibility, %	62.4 ^a	72.0 ^b	71.8 ^b	73.5 ^b	72.8 ^b	.55
Small intestinal N disappearance, g/d	68.1	72.6	87.3	93.3	91.2	6.46
% of N intake	59.0	40.3	47.8	50.6	49.5	4.03
% of N entering	58.6	52.5	58.3	61.5	62.6	3.63
Bacterial N synthesis						
gN/kg OMD _{APP}	23.4	23.9	23.0	26.6	22.4	1.53
gN/kg OMD _{TRUE}	17.5	17.5	17.9	19.0	17.1	.97

abcdLS means in the same row with unlike superscripts differ (P<.05).

TABLE 4. SOYBEAN NITROGEN INTAKE AND DIGESTION BY STEERS.

Item	Basal	Raw	285°F	300°F	315°F
Intake of soybean N, g/d	-	65.0	67.3	67.4	68.4
Duodenal soybean N, g/d	-	20.9	36.4	32.0	27.3
Ruminal soybean N disappearance, g/d	-	44.0	30.9	35.4	41.1
% intake	-	67.8	45.9	52.6	60.1
Small intestine soybean N disappearance, g/d	-	3.6	21.7	22.6	21.6
% entering	-	17.2	59.7	70.6	79.2
% intake	-	5.5	32.3	33.5	31.6

TABLE 5. FLOW OF AMINO ACIDS TO THE SMALL INTESTINE OF STEERS FED DIETS CONTAINING RAW OR ROASTED WHOLE SOYBEANS.

Item (g/d)	Basal	Raw	285°F	300°F	315°F	SE
Essential amino acids (EAA)						
Threonine	29.4 ^a	33.9 ^b	38.1 ^c	38.4 ^c	37.5 ^{bc}	1.22
Valine	30.7 ^a	36.2 ^b	40.7 ^{bc}	41.2 ^c	39.1 ^{bc}	1.38
Methionine	8.7	8.7	9.2	9.4	9.7	.59
Isoleucine	29.1 ^a	34.3 ^b	38.3 ^b	38.4 ^b	37.6 ^b	1.25
Leucine	43.7 ^a	52.9 ^b	59.3 ^{bc}	59.9 ^c	57.8 ^{bc}	2.11
Phenylalanine	28.5 ^a	34.5 ^b	38.6 ^{bc}	39.5 ^c	37.8 ^{bc}	1.26
Histidine	11.0 ^a	14.1 ^b	15.8 ^{bc}	16.2 ^c	15.5 ^{bc}	.62
Lysine	37.5 ^a	43.5 ^b	48.1 ^b	48.6 ^b	47.8 ^b	1.63
Arginine	23.5	30.9	35.2	35.8	34.7	1.20
Total EAA	242.0 ^a	288.9 ^b	323.2 ^{bc}	327.4 ^c	317.6 ^{bc}	10.61
Non-essential amino acids (NEAA)						
Aspartate	62.0 ^a	74.8 ^b	84.4 ^c	85.2 ^c	82.8 ^{bc}	2.78
Serine	24.4 ^a	29.9 ^b	34.0 ^c	34.4 ^c	33.2 ^{bc}	1.17
Glutamate	71.2 ^a	90.7 ^b	102.0 ^b	102.3 ^b	98.7 ^b	3.69
Proline	22.9 ^a	28.9 ^b	32.4 ^b	32.3 ^b	31.1 ^b	1.13
Glycine	35.0	39.5	40.1	42.2	41.4	1.61
Alanine	32.9 ^a	38.2 ^b	41.9 ^{bc}	43.0 ^c	41.1 ^{bc}	1.42
Tyrosine	20.8 ^a	24.2 ^b	27.3 ^b	27.5 ^b	27.0 ^b	1.04
Total NEAA	269.2 ^a	326.2 ^b	362.0 ^{bc}	366.8 ^c	355.2 ^{bc}	12.33
Total AA	511.2 ^a	615.0 ^b	685.3 ^{bc}	694.2 ^c	672.8 ^{bc}	22.89

^{abc}LS means in the same row with unlike superscripts differ ($P < .05$).

TABLE 6. RUMINAL NH₃, pH, AND VOLATILE FATTY ACID (VFA) CONCENTRATIONS IN STEERS FED RAW OR ROASTED WHOLE SOYBEANS.

Item	Basal	Raw	285°F	300°F	315°F	SE
NH ₃ , mg/dl	9.8 ^a	15.0 ^{ab}	13.3 ^{ab}	14.9 ^{ab}	16.1 ^b	1.69
pH	6.60	6.67	6.68	6.65	6.62	.028
VFA, mol/100mol						
Acetate	67.2	66.8	67.7	67.0	67.3	.39
Propionate	15.6	14.7	14.6	16.1	15.5	.39
Butyrate	14.0 ^{bc}	14.5 ^c	14.3 ^c	13.2 ^a	13.6 ^{ab}	.24
Isobutyrate	.9 ^a	1.2 ^c	1.0 ^b	1.1 ^b	1.0 ^b	.02
Valerate	.9 ^{ab}	1.1 ^c	1.0 ^{bc}	1.1 ^c	1.1 ^c	.03
Isovalerate	1.4	1.7	1.5	1.5	1.5	.07
Total VFA, mM	64.7	61.4	66.7	62.6	64.6	3.38

^{abc}LS means in the same row with unlike superscripts differ (p<.05).

EFFECTS OF HYDROCHLORIC ACID-TREATED NEWSPRINT IN GROWING LAMB DIETS

B. W. Wolf, L. L. Berger and G. C. Fahey, Jr.

INTRODUCTION

Approximately 15 million tons of newsprint (NP) are used each year in this country. Currently, one-third of all used newspapers are being collected for recycling, with the remainder entering landfills (Landers, 1989). Old newspapers are accumulating faster than they can be recycled and will eventually be dumped in landfills unless alternative uses are found. With over 100 million cattle in this country, all the newspapers produced could easily be fed if they were of sufficient nutritive value to merit inclusion in diets fed under practical production conditions. Previous research showed that untreated NP has limited value in ruminant diets because rate of digestion is so slow that the animal cannot consume enough digestible energy (Dinus and Oltjen, 1972; Sherrod and Hansen, 1973). Belyea et al. (1987) suggested that chemical and physical treatments could enhance digestibility of paper. Walker and Kohler (1981) reported increased digestibility and performance by ruminants fed treated vs untreated cellulose. The primary objective of this experiment was to evaluate nutrient intake and apparent digestibility of HCl-treated NP versus a control alfalfa hay diet when fed to sheep.

MATERIALS AND METHODS

Fifteen Suffolk, Hampshire, and Dorset rams and wethers with a mean body weight (BW) of 33.9 kg (range: 25.6 to 41 kg) were used in a feed intake and nutrient digestibility experiment consisting of one 21-day (d) period. During the first 15 d, lambs were allowed to adapt to the feed and digestion crates. This was followed by a 6-d fecal collection phase. Lambs were randomly allotted to the diets so that lambs fed each treatment would have the same mean BW. Total feces were collected and a 25% aliquot from each lamb was saved for further analyses. During the experiment, lambs were individually housed in mesh-bottom crates in a temperature controlled (20°C) room with constant fluorescent lighting. They were fed twice daily at 0600 and 1800.

All lambs were fed a complete mixed diet of 95% roughage and 5% liquid supplement (LS) with alfalfa hay (AH) fed alone or with NP as the roughage source (Table 1). The complete mixed diets were fed ad libitum, allowing for at least 10%orts for the first 12-d. Lambs were fed at restricted intake (2% of BW) from d-13 through 21. Water and trace mineral salt were available continually. Treated NP was fed at 20% and 40% of the DM (Table 1). Lambs did not eat untreated NP in our previous experiment; therefore, it was not included in this experiment. No additional feedstuffs were added to the diet in order to exclude any variable other than level of paper in the experiment. Ingredient and chemical compositions of diets fed to lambs are presented in Table 2.

All NP used for this trial was obtained from Cedar Rapids, Iowa because "The Cedar Rapids Gazette" uses 100% soybean oil based-ink. This NP was chosen to remove any concern about potential toxins from ink with petroleum-based carrier oils (Heichel et al., 1974). Both colored and black and white pages were

used. Whole newspapers were run through a forage chopper twice and stored in cardboard barrels in an unheated building. The HCl-treated NP required for this experiment was prepared at the Animal Sciences Laboratory at the University of Illinois. First, shredded NP was ground through a hammer mill with a 1.27 cm screen. Then, one kg of NP was placed in a bowl mixer and mixed with the acid. Newsprint was treated with 4% HCl (% of NP dry matter) by adding 1 L of 4% HCl to 1 kg of NP. Acid was sprayed on NP in the mixer and allowed to equilibrate and saturate for 15 minutes. Acid-treated NP was then placed in a 15 L ceramic-on-steel kettle (General Housewares Corp.). Newspaper in the kettle then was autoclaved for 4 hours at 125°C and 16 psi. Newspaper then was placed in a cooler and stored until mixing of diets.

The three treatments were: 1) 95% AH, 5% LS; 2) 75% AH, 20% NP, 5% LS; and 3) 55% AH, 40% NP, 5% LS.

Dry matter (DM) intakes were measured daily. Samples of feed were collected on d-14 through 19 and orts were collected on d-16 through 21 and saved for analysis. Samples were dried at 55°C, ground through a Wiley mill (2 mm screen), and composited. Feces, feeds, and orts were analyzed for DM and organic matter (OM) (AOAC, 1975). Nitrogen was measured using the Kjeldahl method (Bradstreet, 1965). Neutral detergent fiber (NDF) was measured using the procedure of Robertson and Van Soest (1977) as modified by Jeraci et al. (1988). Acid detergent fiber (ADF) and acid detergent lignin (ADL) were measured according to Goering and Van Soest (1970). Body weights were taken on d-1 and d-21.

Data were analyzed by analysis of variance for a completely randomized design (CRD) according to the General Linear Models (GLM) procedure of SAS (1985). Model sums of squares for the CRD included treatment effects. Treatment mean differences for effects of diet were separated using the LSD method. A single observation was lost from treatment three for reasons unrelated to treatment.

RESULTS AND DISCUSSION

Chemical composition of feeds used in the digestibility trial is presented in Table 2. Neutral detergent fiber and ADF values (74.5 and 74.7, respectively) were nearly equal for the HCl-treated NP. This may show that the hemicellulose fraction of the NP was completely solubilized by the HCl treatment. Hydrochloric acid-treated NP was higher in cell wall carbohydrates compared to alfalfa hay. Newsprint was very low in CP (0.3%).

Nutrient intakes, apparent nutrient digestibilities, and digestible nutrient intakes are presented in Table 3. Dry matter intakes were similar for all treatments. However, apparent DM digestibility decreased ($P < .05$) with increasing levels of HCl-treated NP. Digestible DM intake was decreased ($P < .05$) for the 40% HCl-treated NP diet (322 g/d) vs the control diet (446 g/d). This may be explained by the lower apparent DM digestibility of HCl-treated NP diets. Assuming that AH in the HCl-treated NP diets is digested to the same extent as the control AH diet, HCl-treated NP had a DM digestibility of approximately 21%.

Organic matter intake and apparent OM digestibility followed similar trends to those of DM. Organic matter digestibility and digestible OM intake decreased ($P < .05$) with increasing levels of HCl-treated NP in the diet.

Apparent crude protein (CP) digestibilities by lambs decreased ($P < .05$) with increasing levels of HCl-treated NP. This suggests that site of digestion was shifted to the large intestine where bacterial fermentation could result in larger amounts of protein being excreted in feces, thus lowering apparent CP digestibility.

Neutral detergent fiber and ADF followed similar trends. Both, NDF and ADF apparent digestibilities decreased ($P < .05$) with increasing levels of HCl-treated NP. Lambs fed the HCl-treated NP diets consumed, on average, 79 g/d more ADF vs lambs fed the control diet. This may be explained by the fact that NP contained higher amounts of structural carbohydrates.

In summary, growing lambs fed diets containing HCl-treated NP had similar intakes to lambs fed the AH control diet. However, lambs fed the AH control diet had higher nutrient digestibilities. In order for NP to be used in practical ruminant diets, it must have higher digestibility values than those observed in this experiment.

REFERENCES

- AOAC. 1975. Official Methods of Analysis (12th Ed.). Association of Official Analytical Chemists, Washington, DC.
- Belyea, R.L., F.A. Martz, M. Madhisetty and T.P. Davis. 1987. Intake, digestibility and energy utilization of corrugated paper diets. Anim. Feed Sci. Tech. 17:57.
- Bradstreet, R.B. 1965. Kjeldahl method for organic nitrogen. Academic Press. New York.
- Dinius, D.A. and R.R. Oltjen. 1972. Effect of newsprint on ration palatability and ruminoreticular parameters of beef steers. J Anim. Sci. 34:137.
- Goering, H.K. and P.J. Van Soest. 1970. Forage fiber analyses. USDA Agric. Handbook 379. Washington, DC.
- Heichel, G.H., L. Hankin and R.A. Botsford. 1974. Lead in paper: a potential source of food contamination. J. Milk Food Technol. 37:499.
- Jeraci, J.L., T. Hernandez, J.B. Robertson and P.J. Van Soest. 1988. New and improved procedure for neutral detergent fiber. J. Anim. Sci. 66(Suppl. 1):351 (Abstr.).
- Landers, R.K. 1989. America turns to recycling. Editorial Research Reports 2:650.
- Robertson, J.B. and P.J. Van Soest. 1977. Dietary fiber estimation in concentrate feedstuffs. J. Anim. Sci. 45(Suppl. 1):254 (Abstr.).
- SAS. 1985. SAS User's Guide: Statistics. SAS Inst. Inc., Cary, NC.

Sherrod, L.B. and K.R. Hansen. 1973. Newspaper levels as roughage in ruminant rations. J. Anim. Sci. 36:592.

Walker, H.G. and G.O. Kohler. 1981. Treated and untreated cellulosic wastes as animal feeds: recent work in the United States of America. Agriculture and Environment 6:229.

TABLE 1. INGREDIENT COMPOSITION OF DIETS

Item	Diet		
	1	2	3
	----- % DM -----		
Alfalfa hay ^a	94.7	74.8	55.4
Liquid supplement ^b	5.3	5.6	5.6
HCl-treated NP ^c	-	19.6	39.0

^aChopped alfalfa hay.

^bLiquid supplement was molasses-based.

^cHCl-treated NP = hydrochloric acid-treated newsprint.

TABLE 2. CHEMICAL COMPOSITION OF FEEDS USED IN GROWING LAMB DIETS

Ingredient	Chemical component					
	DM ^a	OM	CP	NDF	ADF	ADL
	----- % DM -----					
Alfalfa hay ^b	88.9	93.0	15.8	47.5	36.7	8.7
Liquid suppl. ^c	56.6	82.6	29.2	0.0	0.0	0.0
HCl-treated NP ^d	42.4	97.1	0.3	74.5	74.7	30.1

^aDM on an as-fed basis.

^bChopped alfalfa hay.

^cLiquid supplement was molasses based.

^dHCl-treated NP = hydrochloric acid-treated newsprint.

TABLE 3. LEAST SQUARES MEANS FOR NUTRIENT INTAKE, APPARENT NUTRIENT DIGESTIBILITY, AND DIGESTIBLE NUTRIENT INTAKE OF CHEMICALLY TREATED NEWSPRINT DIETS FED TO GROWING LAMBS

	Diet ^a			
Item	1	2	3	SEM ^b
Intake, g/d				
DM	694	711	684	57.5
OM	641	663	643	53.5
CP	114 ^x	96 ^x	72 ^y	7.9
NDF	312	357	380	28.7
ADF	241 ^x	300 ^{x,y}	339 ^y	24.4
Apparent digestibility, %				
DM	64.4 ^x	55.9 ^y	47.0 ^z	.73
OM	64.7 ^x	55.5 ^y	46.8 ^z	.76
CP	74.7 ^x	67.5 ^y	51.9 ^z	1.35
NDF	47.0 ^x	35.7 ^y	25.8 ^z	1.16
ADF	44.4 ^x	30.9 ^y	23.4 ^z	1.24
Digestible nutrient intake, g/d				
DM	446 ^x	398 ^{x,y}	322 ^y	33.3
OM	414 ^x	369 ^{x,y}	303 ^y	31.0
CP	85 ^x	65 ^y	38 ^z	5.4
NDF	146 ^x	127 ^{x,y}	99 ^y	11.0
ADF	106 ^x	93 ^{x,y}	80 ^y	8.7
Intake,				
% of BW	2.04	2.06	2.04	.03

^aDiet 1 = 95% alfalfa hay (AH), 5% molasses (M); Diet 2 = 75% AH, 5% M, 20% HCl-treated NP; Diet 3 = 55% AH, 5% M, 40% HCl-treated NP.

^bSEM = standard error of treatment mean. For treatment means with unequal observations, the highest SE was recorded.

^{x,y,z}Means in the same row without a common superscript letter differ (P<.05).

EFFECTS OF TREATED AND UNTREATED NEWSPRINT IN GROWING LAMB DIETS

B. W. Wolf, L. L. Berger and G. C. Fahey, Jr.

INTRODUCTION

Over 160 million tons of municipal solid waste (MSW) are produced each year. This material is a pollutant and no matter how well managed, will have a great environmental impact (Sussman, 1989). To bring this problem under control, we must reduce the MSW stream entering U.S. landfills. According to the Environmental Protection Agency (EPA), over 70 percent of the 14,000 landfills that were in operation in 1978 have closed; only 3,300 will still be operating in 1993. The rising cost of waste disposal and community opposition of siting new landfills or building new incinerators has caused increased efforts to recycle. Currently, only 11% of the nation's waste is recycled, 9% is burned and 80% is put into landfills (Landers, 1989).

According to the EPA, paper and paperboard comprise 41 percent of our MSW. As a result of increased efforts to recycle, the collection of newsprint from 1983 to 1988 increased 34 percent and continues to rise. As the supply of newsprint (NP) increases, recyclers who once paid \$30 or more per ton of old newspapers now charge cities to haul it away. Only one-third of the more than 14 million tons of NP used in the United States each year is recycled, and old newspapers are accumulating faster than they can be used. Alternative uses for NP must be found.

Newsprint contains approximately 55% cellulose (Belyea et al., 1979a; Rivers and Emert, 1988). Ruminant animals are an efficient converter of cellulose products into human food. Via microbial action in their reticulo-rumen, they have the ability to utilize large quantities of cellulose as energy. Therefore, the potential exists that ruminants could digest and utilize NP efficiently as a dietary source of energy (Daniels et al., 1970). Several researchers have tried to use recycled NP as a feed source for ruminants with little success (Belyea et al., 1979, 1987; Dinius and Oltjen, 1972; Hawkins et al., 1969; Mertens et al., 1971; Sherrod and Hansen, 1973). The primary problem has been that the NP is so slowly degraded in the rumen that the animal is satiated before it consumes enough digestible energy to meet its requirement.

Belyea et al. (1987) suggested that chemical and physical treatments could enhance digestibility of paper. Walker and Kohler (1981) reported increased digestibility and performance by ruminants fed treated vs untreated cellulose. The primary objective of this experiment was to determine the effects of HCl treatment of NP on its subsequent nutrient intake and apparent digestibility when fed to sheep.

MATERIALS AND METHODS

Twenty-five Suffolk, Hampshire, and Dorset rams and wethers with a mean body weight (BW) of 28.9 kg (range: 21.1 to 34.8 kg) were used in a feed intake and nutrient digestibility experiment consisting of one 22-day (d) period. During the first 16-d, lambs were allowed to adapt to the feed and digestion crates. This was followed by a 6-d fecal collection phase. Lambs were randomly allotted to the diets so that each treatment would have the same mean BW. Total feces were collected and a 15% aliquot from each lamb was saved for further

analyses. During the experiment, lambs were individually housed in elevated mesh bottom crates in a temperature controlled (23°C) room with constant fluorescent lighting. They were fed twice daily at 0700 and 1700.

All lambs were fed a complete mixed diet of 95% roughage and 5% liquid supplement (LS) with alfalfa hay (AH) fed alone or with NP as the source of roughage (Table 1). The complete mixed diets were fed ad libitum, allowing for at least 10%orts for the first 13-d. Lambs were fed at restricted intake [treatment (trt.) 1, 2, and 3 at 3.2% BW and trt. 4 and 5 at 2% BW] from d-14 through 22. Diets were restricted according to adjustment period intakes. Water was available continually. Treated and untreated NP were fed at 20% and 40% of the DM, respectively (Table 1). Trace mineral salt was available continually. No additional feedstuffs were added to the diet so that no variable, other than level of paper, would be introduced into the experiment. Ingredient and chemical composition of diets fed to lambs are presented in Table 2.

All NP used for this experiment was obtained from "The Cedar Rapids Gazette", Cedar Rapids, Iowa. This NP was chosen because all ink is 100% soybean oil-based, thus removing any concern about high levels of toxin from ink with petroleum-based carrier oils (Heichel et al., 1974). Both colored and black and white pages were used. Whole newspapers were chopped through a forage chopper twice and stored in cardboard barrels in an unheated building. The HCl-treated NP required for the experiment was prepared at the Animal Science Laboratory at the University of Illinois. One kilogram of NP was placed in a 15 L ceramic-on-steel kettle made by General Housewares Corporation. Newsprint was treated with 2% HCl (% of NP DM) by adding 4 L of 0.5% HCl to 1 kg of NP. Acid and NP were hand-mixed in kettles and allowed to equilibrate and saturate for 30 minutes. Newsprint was autoclaved for 4 hours at 125°C and 16 psi. Newsprint then was placed in sinks and excess liquid was hand squeezed from the NP. Before mixing into diets, NP was ground through a hammer mill without a screen to break up any large chunks. Complete diets were mixed prior to feeding. Untreated NP was ground through a hammer mill (1.27 cm screen) and water was added to untreated NP to give it a similar percent moisture as HCl-treated NP.

The five treatments were: 1) 95% AH, 5% LS; 2) 75% AH, 20% HCl-treated NP, 5% LS; 3) 55% AH, 40% HCl-treated NP, 5% LS; 4) 75% AH, 20% NP, 5% LS; 5) 55% AH, 40% NP, 5% LS.

Dry matter (DM) intakes were measured daily. Samples of feed were collected on d 14 through 20 and orts were collected on d 17 through 22 and saved for analysis. Samples were dried at 55°C, ground through a Wiley mill (2 mm screen), and composited. Feces, feed, and orts were analyzed for DM and OM (AOAC, 1975). Nitrogen was measured using the Kjeldahl method (Bradstreet, 1965). Neutral detergent fiber (NDF) was measured using the procedure of Robertson and Van Soest (1977) as modified by Jeraci et al. (1988). Acid detergent fiber (ADF) and acid detergent lignin (ADL) were measured according to Goering and Van Soest (1970). Body weights were taken on d-1 and d-22.

Data were analyzed by analysis of variance for a completely randomized design (CRD) according to the General Linear Models (GLM) procedure of SAS (1985). Model sums of squares for the CRD included treatment effects. Treatment mean differences for effects of diet were separated using the LSD method only

when protected by a significant F-test ($P < .05$). A single observation was lost from treatment three for reasons unrelated to treatment.

RESULTS AND DISCUSSION

Chemical composition of feeds used in the digestibility trial is presented in Table 2. Treatment of NP with HCl appeared to solubilize a portion of the structural carbohydrate fraction of the cell wall matrix when compared with untreated NP. However, NDF and ADF values (82.4 and 82.4, respectively) were equal for the HCl-treated NP. This may show that HCl treatment of NP completely solubilized the hemicellulose fraction of the NP. Both HCl-treated NP and untreated NP were higher in cell wall carbohydrates compared to alfalfa hay.

Nutrient intakes, apparent nutrient digestibilities, and digestible nutrient intakes are presented in Table 3. Dry matter intakes and digestible DM intakes were increased ($P < .05$) such that lambs fed HCl-treated NP diets consumed, on average, 456 g/d and 214 g/d more DM and digestible DM, respectively, than lambs fed untreated NP diets. However, apparent DM digestibilities of diets 2 and 3 (52.6% and 44.8%, respectively) are comparable to those of diets 4 and 5 (52.0% and 48.2%, respectively). This may be explained by the fact that lambs fed diets 4 and 5 selectively sorted NP out and consumed mostly AH. Intake, expressed as a percentage of BW, was increased ($P < .05$) to 3.1% for lambs fed HCl-treated NP diets vs 1.9% and 1.3% for lambs fed untreated NP diets 4 and 5, respectively. During ad libitum intake, consumption was nearly equal for lambs fed the 40% HCl-treated NP and AH diets (Table 3). These data are interpreted to suggest that acid-treated NP may replace AH up to 40% of the diet DM without depressing intake. Untreated NP, on the other hand, decreased intake at 20% of the diet. Assuming that AH in the HCl-treated NP diets was digested to the same extent as in the control AH diets, HCl-treated NP is approximately 21% digestible. Digestibility of untreated NP cannot be calculated from these data since lambs sorted the NP and had much lower DM intakes.

Organic matter (OM) intake and apparent OM digestibility followed similar trends to that of DM, with lambs fed the HCl-treated NP diets consuming more (844 g/d) than lambs fed the untreated NP (460 g/d). Hydrochloric acid treatment of NP resulted in 197 g/d more digestible OM intake by lambs fed diets 2 and 3 vs diets 4 and 5. Organic matter digestibility and digestible OM intake decreased with increasing levels of HCl-treated NP and untreated NP in the diet.

Apparent crude protein (CP) digestibilities by lambs decreased with increasing levels of NP. This suggests that site of digestion was shifted to the large intestine where bacterial fermentation could result in larger amounts of protein being excreted in feces, thus lowering apparent CP digestibility. Acid treated NP diets had increased ($P < .05$) digestible CP intakes (70 g/d) vs untreated NP diets (42 g/d) due to higher levels of intake.

Lambs fed the HCl-treated NP diets consumed, on average, 176 g/d digestible NDF while lambs fed untreated NP diets consumed 96 g/d digestible NDF. This is a 1.8-fold increase in digestible NDF intake. However, digestibilities of NDF for diets 2 and 3 (37.9% and 30.1%, respectively) were similar to those of diets 4 and 5 (39.0% and 33.9%, respectively). Again, sorting by lambs fed untreated NP diets and lower intakes may explain this similarity. Neutral detergent fiber intake of lambs was increased (523 g/d) for HCl-treated NP diets vs lambs fed the AH diet (435 g/d).

Acid detergent fiber intakes and digestibilities followed similar trends to those of NDF. Hydrochloric acid treatment of NP increased ($P < .05$) digestible ADF intake by 83 g/d when compared to untreated NP diets, a 2.1-fold increase. Intakes of ADF were increased for HCl-treated NP diets (491 g/d) vs the AH diet (389 g/d) due to the higher cell wall carbohydrate content in NP compared to AH.

In summary, growing lambs fed diets containing HCl-treated NP had higher nutrient intakes when compared to lambs fed the untreated NP diets. In addition, lambs fed HCl-treated NP-containing diets had similar intakes to lambs fed the AH control diet. However, lambs fed the AH control diet had increased nutrient digestibilities when compared to HCl-treated and untreated NP containing diets. Although HCl treatment of NP improved nutrient intakes, nutrient digestibilities of treated diets were poor and should be of first priority in future studies.

REFERENCES

- AOAC. 1975. Official Methods of Analysis (12th Ed.). Association of Official Analytical Chemists, Washington, DC.
- Belyea, R.L., B.K. Darcy and K.S. Jones. 1979. Rate and extent of digestion and potentially digestible cell wall of waste papers. *J Anim. Sci.* 49:887.
- Belyea, R.L., F.A. Martz, M. Madhisetty and T.P. Davis. 1987. Intake, digestibility and energy utilization of corrugated paper diets. *Anim. Feed Sci. Tech.* 17:57.
- Bradstreet, R.B. 1965. Kjeldahl method for organic nitrogen. Academic Press. New York.
- Daniels, L.B., J.R. Campbell, F.A. Martz and H.B. Hedrick. 1970. An evaluation of newspaper as feed for ruminants. *J. Anim. Sci.* 30:593.
- Dinius, D.A. and R.R. Oltjen. 1972. Effect of newsprint on ration palatability and ruminoreticular parameters of beef steers. *J Anim. Sci.* 34:137.
- Goering, H.K. and P.J. Van Soest. 1970. Forage fiber analyses. USDA Agric. Handbook 379. Washington, DC.
- Hawkins, G.E., J.R. Stevenson, A. Baham and D.R. Rao. 1969. Preliminary comparison of microbial activity in dairy cows fed a paper ration and a conventional ration. *J. Dairy Sci.* 52:555.
- Heichel, G.H., L. Hankin and R.A. Botsford. 1974. Lead in paper: a potential source of food contamination. *J. Milk Food Technol.* 37:499.
- Landers, R.K. 1989. America turns to recycling. *Editorial Research Reports* 2:650.
- Mertens, D.R., J.R. Campbell, F.A. Martz and E.S. Hilderbrand. 1971. Lactational and ruminal response of dairy cows to ten and twenty percent dietary newspaper. *J. Dairy Sci.* 54:667.
- Rivers, D.B. and G.H. Emert. 1988. Factors affecting the enzymatic hydrolysis of municipal-solid-waste components. *Biotechnol. Bioeng.* 31:278.

- Robertson, J.B. and P.J. Van Soest. 1977. Dietary fiber estimation in concentrate feedstuffs. J. Anim. Sci. 45(Suppl. 1):439.
- SAS. 1985. SAS User's Guide: Statistics. SAS Inst. Inc., Cary, NC.
- Sherrod, L.B. and K.R. Hansen. 1973. Newspaper levels as roughage in ruminant rations. J. Anim. Sci. 36:592.
- Sussman, D.B. 1989. Newspapers-a major contributor to the municipal solid waste stream. United States Environmental Protection Agency's Municipal Solid Waste Technology Conference, San Diego, CA.
- Walker, H.G. and G.O. Kohler. 1981. Treated and untreated cellulosic wastes as animal feeds: recent work in the United States of America. Agriculture and Environment 6:229.

TABLE 1. INGREDIENT COMPOSITION OF DIETS

Item	Diet ^a				
	1	2	3	4	5
	----- % DM -----				
Alfalfa hay	95.2	75.7	56.3	76.1	57.2
Liquid supplement ^b	4.8	4.7	4.7	4.6	4.6
HCl-treated NP ^c	-	19.6	39.0	-	-
NP ^d	-	-	-	19.3	38.3

^aTrace minerals were available free choice.

^bLiquid supplement was molasses-based.

^cHCl-treated NP = hydrochloric acid-treated newsprint.

^dNP = untreated newsprint.

TABLE 2. CHEMICAL COMPOSITION OF FEEDS USED IN GROWING LAMB DIETS

Ingredient	Chemical component					
	DM ^a	OM	CP	NDF	ADF	ADL
	----- % DM -----					
Alfalfa hay ^b	86.4	90.5	17.3	50.0	44.6	9.8
Liquid suppl. ^c	55.1	81.6	27.5	0.0	0.0	0.0
HCl-treated NP ^d	25.6	97.2	0.7	82.4	82.4	27.2
NP ^e	90.0	98.6	0.3	95.5	80.8	23.0

^aDM on an as-fed basis.

^bChopped alfalfa hay.

^cLiquid supplement was molasses based.

^dHCl-treated NP = hydrochloric acid-treated newsprint.

^eNP = newsprint.

TABLE 3. LEAST SQUARES MEANS FOR NUTRIENT INTAKE, APPARENT NUTRIENT DIGESTIBILITY, AND DIGESTIBLE NUTRIENT INTAKE OF CHEMICALLY TREATED OR UNTREATED NEWSPRINT DIETS FED TO GROWING LAMBS

	Diet ^a					
Item	1	2	3	4	5	SEM ^b
Intake, g/d						
DM	914 ^w	914 ^w	918 ^w	544 ^x	376 ^y	54.6
OM	823 ^w	836 ^w	851 ^w	499 ^x	352 ^y	49.9
CP	162 ^w	133 ^x	104 ^y	82 ^y	50 ^z	8.4
NDF	435 ^x	493 ^{w,x}	553 ^w	299 ^y	220 ^z	29.3
ADF	389 ^x	456 ^{w,x}	525 ^w	263 ^y	191 ^z	26.7
Apparent digestibility, %						
DM	60.7 ^w	52.6 ^x	44.8 ^y	52.0 ^x	48.2 ^y	1.2
OM	62.1 ^w	53.5 ^x	45.8 ^z	53.5 ^x	49.9 ^y	1.2
CP	66.9 ^w	62.6 ^x	53.8 ^y	63.7 ^x	61.9 ^x	1.0
NDF	48.3 ^w	37.9 ^x	30.1 ^y	39.0 ^x	33.9 ^{x,y}	2.0
ADF	52.4 ^w	39.4 ^x	31.4 ^y	41.9 ^x	35.0 ^y	1.3
Digestible nutrient intake, g/d						
DM	555 ^w	480 ^x	411 ^x	283 ^y	180 ^z	27.3
OM	510 ^w	446 ^{w,x}	389 ^x	267 ^y	175 ^z	25.7
CP	108 ^w	83 ^x	56 ^y	52 ^y	31 ^z	5.1
NDF	210 ^w	186 ^{w,x}	165 ^x	117 ^y	74 ^z	11.0
ADF	203 ^w	179 ^{w,x}	165 ^x	111 ^y	67 ^z	10.3
Intake, % of BW						
Set ^c	3.2 ^w	3.1 ^w	3.1 ^w	1.9 ^x	1.3 ^y	.04
Ad lib ^d	3.5 ^w	3.6 ^w	3.5 ^w	2.0 ^x	1.5 ^x	.28

^aDiet 1 = control; Diet 2 = 20% HCl-NP; Diet 3 = 40% HCl-NP; Diet 4 = 20% NP; Diet 5 = 40% NP.

^bSEM = Standard error of treatment means. For treatment means with unequal observations the greatest SE was recorded.

^cSet = lamb intakes during collection period.

^dAd lib = ad libitum lamb intakes averaged over d 9-13.

^{w,x,y,z}Means in the same row lacking a common superscript letter differ (P<.05).

EFFECT OF PRENATAL ANDROGENIZATION UPON PERFORMANCE, LACTATION, CARCASS, AND SENSORY TRAITS OF HEIFERS IN A SINGLE CALVING HEIFER SYSTEM

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SUMMARY

Eight prenatally androgenized (PA) and 8 control heifers were bred and calved in early 1992. Following a 4-5 wk adjustment period, pairs were moved into feedlot pens equipped with pinpointer feeding devices. Heifers were fed a high energy finishing ration while nursing. Performance and milk production data were collected for the cow-calf pairs until calves were weaned at 120 d of age. The heifers were kept on feed until determined to possess 1.0 cm subcutaneous fat cover, at which time they were weighed and slaughtered at the University of Illinois Meat Laboratory. Twenty-four h post-mortem, carcass data was collected and samples taken for sensory analysis. During the pre-weaning trial, PA heifers gained .5 kg (1.10 lbs) faster ($P < .05$) than controls and were more efficient ($P < .05$). Combined cow-calf gain was 2.99 kg/d (6.59 lbs/d) and 2.40 kg/d (5.29 lbs/d) for PA and control groups, respectively. Combined cow-calf gain/feed ratios pre-weaning were .175 (5.71 lbs feed/lb gain) and .146 (6.85 lbs feed/lb gain) for PA and controls, respectively. These performance records were accomplished as the heifers were simultaneously producing over 8 kg (17.6 lbs) and 7 kg (15.4 lbs) milk per d for PA and control heifers, respectively, throughout the pre-weaning trial. Differences in milk production and composition were not significant. Post-weaning gains and efficiencies were low as cattle had already obtained market readiness at the time of weaning. Dressing percentages were relatively low (59.41 and 59.25%) due to increased udder size of the heifers. Maturity scores were not affected by treatment, although PA actually decreased lean maturity values ($P < .05$). None of the single calf heifers graded C maturity (hard bone). Sensory analysis indicated no differences between PA and control carcasses.

INTRODUCTION

Prenatal androgenization (PA) involves the exposure of the fetus to increased levels of gonadal steroids. The net effect upon the brain is increased masculinization of the fetus, regardless of sex (Gorski and

Jacobson, 1982). Thus, there has been tremendous interest in the effects of PA upon growth, carcass traits, and reproductive efficiency of farm animals. Klindt et al. (1986) concluded that prenatally androgenized ewe lambs had greater potential for post-weaning growth. Significant improvements of more than 10% have been shown for post-weaning average daily gains and feed efficiency of ewes exposed to prenatal testosterone derivatives compared to control ewes (DeHaan et al., 1987; Jenkins et al., 1988). Heifers exposed to PA beginning between d 80 to 110 of gestation have gained 19.5% faster than controls to a constant weight of 475 kg (DeHaan et al., 1988) and were higher performing when fed to a constant compositional endpoint of 1.2 cm subcutaneous fat cover (DeHaan et al., 1990).

PA also appears to enhance carcass composition. PA females tend to have less subcutaneous fat cover and more desirable yield grades than controls at the same slaughter weight (DeHaan et al., 1987).

Reproductive functionality of PA females is a pertinent issue regarding their usefulness in various livestock management systems. PA has been shown to cause the elimination of regular estrous cycles and external genitalia changes in the ewe (Clarke et al., 1976; Clarke, 1977; DeHaan et al., 1987). In contrast, challenge tests with exogenous estradiol to PA heifers produced surges of luteinizing hormones similar in magnitude and occurrence as that of control heifers (Hamernik et al., 1987). Work at the University of Illinois has indicated that first breeding conception rates of PA and control heifers were similar, however, after parturition conception rates of PA heifers declined (unpublished data).

Single calving heifer (SCH) systems involve the breeding of heifers to produce one calf followed by feedlot finishing and marketing of the heifer. Several researchers have concluded the system is economically more efficient than conventional cow-calf operations as reproduction and growth for meat production is achieved by one animal and the costs of retaining females from year to year eliminated (Taylor et al., 1985; Sell et al., 1988; Brethour and Jaeger, 1989; Waggoner et al., 1990).

Two factors of primary importance to the successful implementation of a SCH system include minimization of dystocia (Boucque et al., 1980; Bailey et al., 1991) and processing of heifers prior to 30 months of age. Thirty months is not an absolute, but a guideline, for which many cattle will be

subjectively classified as C maturity and no longer eligible for the choice and select grades of beef which offer significantly greater economic returns to the producer.

Thus, the objectives of this study were to evaluate the effects of PA upon pre- and post-weaning performance, lactation, carcass merit, and sensory traits of heifers in a SCH system.

MATERIALS AND METHODS

Eight PA and control heifers of Angus/Hereford breeding from the Dixon Springs Agricultural Research Center were transported to the Urbana Beef Center and utilized for this study. PA was accomplished by inserting four 15 cm testosterone propionate (TP) implants subcutaneously posterior (behind) the scapula (shoulder) and over the rib cage on the left side of the pregnant cow. Implantation was administered between d 80 and 110 of gestation. The TP implants, made of a medical-grade silastic tubing, contain approximately 2.25 g of crystalline TP and provide an average secretion rate of 37.8 mg TP per day (Kesler, 1987). Implants were removed 3 weeks prior to calving. Heifer calves born to these implanted cows were then reared as normal replacements and bred at approximately 15 months of age.

Calving of PA and control heifers occurred at approximately 2 yr of age. Routine calving procedures were followed. Twenty-eight to 35 d post-partum, heifers and calves were weighed on each of 2 consecutive days and moved to drylot pens equipped with 4000B pinpointter feeding devices. Heifers were gradually adjusted to a high energy "finishing" ration (Table 1) formulated to meet or exceed NRC (1984) requirements. Individual feed intakes were recorded throughout the trial, and interim weights were taken every 28 days.

Milk production was measured at approximately 42, 84, and 110 days post-partum. The day prior to milking, calves were separated from dams at 1300 h (1 pm). At 1945 h (7:45 pm) calves were allowed to nurse until 2000 h (8 pm). This effectively removed all milk from the udder. Calves were again separated from their dam until after milking the next day. The next morning at 0800 h (8:00 am), heifers were given 5 cc (100 U.S.P. units) of oxytocin intramuscularly and milked by machine. Twelve hour milk weights were multiplied by two to yield a 24-h production. Milk

samples were collected and analyzed for fat and crude protein content by infrared analysis. Solids non-fat was determined by the procedure of Golding (1959).

At 120 d post-partum, heifers and calves were weighed on each of two consecutive days and weaned. Heifers were fed for an additional 8 to 26 days, until determined to possess 1.0 cm (.4 in) subcutaneous fat cover by a real-time linear array ultrasound instrument. Final termination weights again were taken on two consecutive days, and heifers were processed at the University of Illinois Meat Laboratory. At 24 h postmortem, carcasses were evaluated for quality and yield grade traits by trained personnel.

Longissimus dorsi (Ribeye) steaks were collected from each carcass and used for subsequent sensory analyses. These steaks were aged for a period of 7 d, cooked to an internal temperature of 70° C, and served warm to a 6 member experienced taste panel. Steaks were evaluated for tenderness, juiciness, beef flavor, presence of off flavors, and overall palatability by panelists using a 15 cm continuous scale.

The General Linear Models procedure of SAS (1985) was used to assess the significance of the PA treatment in a completely randomized design. For all performance traits, variation due to sex of calf was removed. In analysis of carcass maturity scores and sensory attributes, age of heifer was used as a covariate.

RESULTS AND DISCUSSION

Pre-weaning performance parameters of PA and control heifers and their calves are shown in Table 2. Despite similar ages and breeding of treatment groups, PA heifers weighed 50 kg (110 lbs) heavier ($P < .05$) 3 mo pre-partum and maintained this weight advantage ($P < .05$) through calving until started on trial 1 mo post-partum. DeHaan et al. (1988) found PA heifers to weigh approximately 19 kg ($P < .07$) and 33 kg ($P < .05$) heavier than controls at weaning and one year of age, respectively. As expected with heavier on-test weights, PA heifers tended to consume more feed. However, while PA heifers produced over 8 kg (17.6 lbs) and controls produced more than 7 kg (15.4 lbs) of 4% fat corrected milk per d (Table 5), average daily gain of PA and control heifers was 1.82 kg/d (4.0 lbs/d) and 1.31 kg/d (2.89 lbs/d), respectively. Overall, PA heifers were more efficient ($P < .05$). Gain/feed ratios for PA and control heifers were

.114 (8.77 lbs feed/lb gain) and .089 (11.23 lbs feed/lb of gain). These efficiencies appear relatively low, however, the heifer was lactating, and calf gain must also be considered. Calves gained over 1.4 kg/d (3.08 lbs/d), but treatment differences were not significant. Combined daily gains of the cow-calf pair for the 88 d pre-weaning trial was 2.99 kg/d (6.59 lbs/d) and 2.40 kg/d (5.29 lbs/d) for PA and control heifers, respectively. Correcting for dry matter intake of calves, the combined gain/feed ratios of PA and control heifers were .175 (5.71 lbs feed/lb gain) and .146 (6.85 lbs feed/lb gain), respectively.

Calves were weaned at approximately 120 d of age. Heifers were fed in the post-weaning portion of the trial until determined to possess 1.0 cm (.4 in) subcutaneous fat cover. Because heifers accumulated body fat during the pre-weaning trial greater than expected, most heifers were only fed an additional 2 weeks. Moe et al. (1971) indicated that efficiency of body tissue (fat) deposition was enhanced during late lactation. Most heifers had already achieved market readiness at the time of weaning, and consequently post-weaning feedlot gains and efficiencies (Table 3) were relatively low for both PA and control heifers.

Overall, pre-weaning and post-weaning combined (Table 4), PA heifers were fed 5 d less ($P < .05$), gained .44 kg/d (.97 lbs/d) more ($P < .01$), and were 28% more efficient ($P < .05$) than controls.

Milk production and composition results taken at 6, 12, and 16 wk post-partum are shown in Table 5. Differences due to treatment for all factors evaluated were not significant. Yields and fat content was highest at 6 wk post-partum and declined thereafter for both PA and control heifers as expected. Overall, yields of all heifers were quite high. At 6 wk post-partum, PA and control heifers produced a 24 h 4% fat corrected milk yield of 9.81 kg (21.6 lbs) and 8.36 kg (18.4 lbs), respectively. Cundiff et al. (1974) found Hereford/Angus cows to produce 6.75 kg (14.9 lbs) of 4% fat corrected milk during a 24 h period.

The effects of PA upon carcass merit and sensory attributes of heifers are shown in Table 6. PA heifers were heavier ($P < .01$) at time of slaughter and had heavier ($P < .01$) hot carcass weights than controls. Dressing percentages, however, were similar ($P > .50$) for PA (59.41%) and controls (59.25%). The relatively low values were likely due to increased udder and gastrointestinal size due to the effects of lactation. Also, heifers were

not completely dried down at the time of slaughter.

Fat thickness was similar, as designed into the study, and most other yield grade factors were similar. PA heifers did possess larger ($P < .05$) ribeye areas.

Of greatest concern regarding the use of PA in a SCH system is its effect on maturity and sensory traits. Waggoner et al. (1990) found pregnancy to advance maturity scores, and heifers implanted with Synovex-H (200 mg TP + 20 mg estradiol benzoate) tended to be more skeletally mature. In this study heifers averaged 862 days of age (29 mo). PA had no effect on bone or overall maturity scores. None of the carcasses were evaluated as C maturity (hard boned). Marbling scores and sensory traits of PA and control heifers were not significantly different.

IMPLICATIONS

Heifers fed a high energy finishing ration can efficiently produce weight gain and milk simultaneously. As a result, heifers may produce a calf and be processed by 30 months of age. This allows the females to be eligible for the choice grades of beef. PA significantly increased gains and feed efficiency and resulted in more beef production per female raised. The SCH system and PA appear to synergistically improve the efficiency of beef production. Using these technologies offers opportunities to increase profitability of smaller Midwest cattle producers.

LITERATURE CITED

- Bailey, C. M., C. R. Reid, T. P. Ringkob, Y. O. Koh, and W. D. Foote. 1991. Nulliparous versus primiparous crossbred females for beef. *J. Anim. Sci.* 69:1403.
- Boucque, C. V., L. O. Fiems, B. G. Cottyn, and F. X. Buysse. 1990. Beef production with maiden and once-calved heifers. *Livest. Prod. Sci.* 7:121.
- Brethour, J. R. and J. R. Jaeger. 1989. The single-calf heifer system. *Kansas Agric. Sta. Rep. of Progress* 570.
- Clarke, I. J. 1977. The sexual behavior of prenatally androgenized ewes

observed in the field. J. Reprod. Fertil. 49:311.

- Clarke, I. J., R. J. Scaramuzzi, and R. V. Short. 1976. Effects of testosterone implants in pregnant ewes on their female offspring. J. Embryol. Exp. Morphol. 36:87.
- Cundiff, L. V., K. E. Gregory, F. J. Schwulst, and R. M. Koch. 1974. Effects of heterosis on maternal performance and milk production in Hereford, Angus, and Shorthorn cattle. J. Anim. Sci. 38:728.
- DeHaan, K. C., L. L. Berger, D. J. Kesler, F. K. McKeith, D. L. Thomas, and T. G. Nash. 1987. Effect of prenatal androgenization on lamb performance, carcass composition, and reproductive function. J. Anim. Sci. 65:1465.
- DeHaan, K. C., L. L. Berger, D. J. Kesler, F. K. McKeith, D. B. Faulkner, and G. F. Cmarik. 1988. Effect of prenatal androgenization on growth performance and carcass characteristics of steers and heifers. J. Anim. Sci. 66:1864.
- DeHaan, K. C., L. L. Berger, D. J. Kesler, F. K. McKeith, D. B. Faulkner, G. F. Cmarik, and R. J. Favero. 1990. Effects of prenatal testosterone treatment and postnatal steroid implantation on growth performance and carcass traits of heifers and steers. J. Anim. Sci. 68:2198.
- Golding, N. S. 1959. A solids-not-fat test for milk using density plastic beads as hydrometers. J. Dairy Sci. 42:899 (Abstr.).
- Gorski, R. A. and C. D. Jacobson. 1982. Sexual differentiation of the brain. MIT Press, Cambridge.
- Hamernik, D. L., S. Y. McFarland, D. de Avilla, S. R. Becker, and J. J. Reeves. 1987. Endocrine and body growth traits in heifers exposed to testosterone propionate during early fetal development. J. Anim. Sci. 64:1858.
- Jenkins, T. G., J. J. Ford, and J. Klindt. 1988. Post-weaning growth, feed efficiency, and chemical composition of sheep as affected by prenatal and postnatal testosterone. J. Anim. Sci. 66:1179.

- Kesler, D. J. 1987. Novel approaches and applications of steroid hormone delivery via polydimethylsiloxane. *Proc. Am. Chem. Soc. Div. Poly. Mater. Sci. Eng.* 57:408.
- Klindt, J., T. G. Jenkins, and J. J. Ford. 1986. Effect of prenatal androgen exposure on growth and the secretion of growth hormone (GH) and prolactin (PRL). *J. Anim. Sci.* 65:669.
- Moe, P. W., H. F. Tyrrell, and W. P. Flatt. 1971. Energetics of body tissue mobilization. *J. Dairy Sci.* 54:548.
- NRC. 1984. *Nutrient Requirement os Beef Cattle* (6th Ed.). National Academy Press, Washington, DC.
- NRC. 1989. *Nutrient Requirements of Dairy Cattle* (6th Ed.). National Academy Press, Washington, DC.
- SAS. 1985. *SAS User's Guide: Statistics*. SAS Inst., Inc., Cary, NC.
- Sell, R., D. L. Watt, R. D. Little, and T. A. Petry. 1988. Single-calf heifer system profitability compared to other North Dakota production systems. *Agricultural Economics Report*, North Dakota State University.
- Taylor, S. C., A. J. Moore, R. B. Thiessen, and C. M. Bailey. 1985. Efficiency of food utilization in traditional and sex-controlled systems of beef production. *Anim. Prod.* 40:401.
- Waggoner, A. W., M. E. Dikeman, J. R. Brethour, and K. E. Kemp. 1990. Performance, carcass, cartilage calcium, sensory, and collagen traits of longissimus muscles of open versus 30-month-old heifers that produced one calf. *J. Anim. Sci.* 68:2380.

TABLE 1. COMPOSITION OF DIETS FED^a

Ingredient	Days			
	1 - 7	8 - 14	15 - 21	>22
Ammoniated corn cobs	45	35	25	15
Corn, whole (high moisture)	42	52	62	72
Molasses	3	3	3	3
Pelleted Supplement	10	10	10	10

^aPercent of diet (DM basis).

TABLE 2. EFFECT OF PRENATAL ANDROGENIZATION (PA) UPON PRE-WEANING PERFORMANCE OF HEIFERS AND THEIR CALVES IN A SINGLE CALVING HEIFER SYSTEM

Item	PA	Control	Treatment	
			SEM ^a	Effect ^b
No. of animals	8	8		
Heifer pre-partum wt ^c , kg	434.9	384.7	12.2	.0125
Heifer on-test wt, kg	465.4	414.5	14.7	.0302
Heifer off-test wt, kg	625.1	530.4	18.5	.0034
Heifer dry matter intake, kg	15.87	14.81	.42	.1009
Heifer daily gain, kg/d	1.82	1.31	.12	.0101
Heifer gain/feed ratio	.114	.089	.008	.0465
Calf birth wt, kg	30.5	30.1	1.8	.8963
Calf on-test wt, kg	57.7	63.7	3.8	.2939
Calf off-test wt, kg	159.9	159.9	7.6	.9999
Days on test	88	87	1	.3722
Age of calf @ weaning, d	122	121	2	.7593
Calf dry matter intake, kg	1.41	1.58	.13	.3792
Calf daily gain, kg/d	1.17	1.09	.05	.2859
Combined ^d dry matter intake, kg	17.29	16.39	.47	.2015
Combined ^d daily gain, kg/d	2.99	2.40	.13	.0059
Combined ^d gain/feed ratio	.175	.146	.008	.0223

^aGreatest standard error of treatment means (SEM) reported.

^bProbability of observing a greater F-value.

^cPre-partum wt taken approximately 3 months prior to calving.

^dPerformance of heifer and calf combined for the pre-weaning period.

TABLE 3. EFFECT OF PRENATAL ANDROGENIZATION (PA) UPON THE POST-WEANING FEEDLOT PERFORMANCE OF HEIFERS IN A SINGLE CALVING HEIFER SYSTEM

Item	PA	Control	SEM ^a	Treatment
				Effect ^b
No. of animals	8	8		
Feedlot on-test wt ^c , kg	625.1	530.4	18.5	.0034
Feedlot off-test wt, kg	628.0	540.0	17.3	.0035
Days on feed post-weaning	10	15	2	.0820
Feedlot dry matter intake, kg	12.40	10.34	.50	.0134
Feedlot daily gain, kg/d	.22	.68	.64	.6217
Feedlot gain/feed ratio	.016	.069	.059	.5389

^aGreatest standard error of treatment means (SEM) reported.

^bProbability of observing a greater F-value.

^cFeedlot on-test wt is the same as pre-weaning off-test wt.

TABLE 4. EFFECT OF PRENATAL ANDROGENIZATION (PA) UPON THE OVERALL PERFORMANCE TRAITS OF HEIFERS PRE- AND POST-WEANING

Item	PA	Control	SEM ^a	Treatment
				Effect ^b
No. of animals	8	8		
Total days on feed ^c	99	104	2	.0488
Overall dry matter intake, kg	13.45	12.58	.51	.2473
Overall daily gain, kg/d	1.65	1.21	.09	.0045
Overall gain/feed ratio	.123	.096	.008	.0325

^aGreatest standard error of treatment means (SEM) reported.

^bProbability of observing a greater F-value.

^cPre-weaning and post-weaning phases combined.

TABLE 5. EFFECT OF PRENATAL ANDROGENIZATION (PA) UPON MILK PRODUCTION AND COMPOSITION SAMPLED AT 6, 12, AND 16 WEEKS POST-PARTUM

Item	PA	Control	SEM ^a	Treatment
				Effect ^b
No. of animals ^c	6	8		
Age of calf @ weaning, d	122	121	2	.7593
Calf weaning wt, kg	159.9	159.9	7.6	.9999
6-wk post-partum milking				
24 h actual yield, kg	9.56	8.36	1.04	.3996
24 h 4% FCM ^d yield, kg	9.81	8.28	1.35	.4073
Fat, %	3.99	3.87	.37	.8102
Protein, %	3.51	3.24	.15	.1942
Solids non-fat, %	8.73	8.61	.17	.6121
12-wk post-partum milking				
24 h actual yield, kg	9.57	9.86	.93	.8199
24 h 4% FCM yield, kg	7.06	7.10	.97	.9720
Fat, %	2.06	2.12	.28	.8628
Protein, %	3.80	3.89	.16	.6936
Solids non-fat, %	8.51	8.74	.25	.4963
16-wk post-partum milking				
24 h actual yield, kg	9.98	8.00	.99	.1568
24 h 4% FCM yield, kg	7.19	5.63	1.10	.3067
Fat, %	2.59	1.91	.48	.2967
Protein, %	3.92	3.86	.12	.7061
Solids non-fat, %	9.03	9.02	.16	.9607

^aGreatest standard error of treatment means (SEM) reported.

^bProbability of observing a greater F-value.

^cDue to mastitis infection, only data from 6 non-infected PA heifers was analyzed.

^d4% fat corrected milk (NRC, 1989).

TABLE 6. EFFECT OF PRENATAL ANDROGENIZATION (PA) UPON CARCASS MERIT AND SENSORY ATTRIBUTES OF HEIFERS FROM A SINGLE CALVING HEIFER SYSTEM

Item	PA	Control	SEM ^a	Treatment
				Effect ^b
No. of animals	8	8		
Shrunk live wt, kg	587.9	506.4	16.6	.0033
Hot carcass wt, kg	349.6	299.9	10.2	.0040
Dressing percent	59.41	59.25	.47	.8129
Liver wt, kg	8.87	7.47	.34	.0119
Fat thickness, cm	1.16	1.13	.12	.8511
Ribeye area, cm ²	74.85	65.25	2.99	.0398
% kidney, pelvic, & heart fat	1.75	1.44	.12	.0961
Yield grade ^c	3.21	3.17	.18	.8922
Heifer age, d	851	874	9	.1030
Bone maturity ^d	212	193	15	.4056
Lean maturity ^d	128	162	11	.0491
Overall maturity ^d	167	178	12	.5530
Marbling score ^e	1097	1043	26	.1871
Juiciness ^f	10.94	10.37	.32	.2528
Tenderness ^f	10.62	10.48	.59	.8736
Beef flavor intensity ^f	11.82	11.47	.30	.4582
Off flavor intensity ^f	14.82	14.52	.13	.1548
Overall palatability ^f	11.32	10.88	.43	.5007

^aGreatest standard error of treatment means (SEM) reported.

^bProbability of observing a greater F-value.

^cYield grade = $2.5 + (2.5 \times \text{adj. fat thickness}) + (.0038 \times \text{hot carcass wt.}) + (.2 \times \text{KPH}) - (.32 \times \text{ribeye area})$.

^dMaturity scores: 100=A⁰, 200=B⁰, 300=C⁰.

^eMarbling scores: 900=slight⁰, 1000=small⁰, 1100=modest⁰.

^fEvaluated by a trained sensory panel using a 15 cm continuous scale; 15 = juicy, tender, greater intensity, no off-flavors, greater palatability.

THE EFFECTS OF PRENATAL ANDROGENIZATION UPON DAM PERFORMANCE, CALF PERFORMANCE, AND MILK YIELDS

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SUMMARY

Thirty-seven prenatally androgenized (PA) and fifty control heifers were evaluated for calving, growth, and reproductive performance. PA heifers, themselves, exhibited similar ($P > .50$) birth weights and calving ease scores as control heifers. In addition, there were no significant differences evident for growth characteristics. Although the Simmental based cow herd at the Orr Center showed no differences in pelvic measurements, the Angus/Hereford based cow herd at Dixon Springs found PA heifers to possess a pelvic opening 12cm^2 smaller ($P < .05$) than controls. When these heifers were bred and calved at approximately two years of age, birth weights of calves born to PA and control heifers were similar, however, factors associated with dystocia were more severe amongst the PA first-calf heifers. Potentially due to stress upon the reproductive organs, only 35% of PA heifers were rebred compared to 60% of control heifers. No differences in calving interval existed for those that did rebreed. Seventeen PA and 17 control heifers were additionally milked by machine three times throughout the summer season. No significant differences in milk yield or composition were found. It is potentially possible, however, that energy intake from the Tall Fescue pastures was a limiting factor in the expression of growth and milk production.

INTRODUCTION

Prenatally androgenized (PA) females have been shown to exhibit increased postnatal growth performance in rats (Jansson et al., 1985), sheep (Klindt et al., 1986; DeHaan et al., 1987; Jenkins et al., 1988) and cattle (DeHaan et al., 1988; DeHaan et al., 1990a). However, the reproductive functionality of such females and the performance of their subsequent offspring must also be questioned to fully evaluate the potential usefulness of PA for producers. DeHaan et al. (1987) reported that PA ewe lambs failed to exhibit regular estrous cycles. Hamernik et al. (1987) evaluated the effects of PA and observed the presence of

functional corpora lutea despite increased masculinization of treated heifers and the presence of internal male genitalia. It has also been hypothesized that testosterone may adversely affect placental function (Slob and van der Werff ten Bosch, 1975) resulting in decreased birth weights as reported by DeHaan et al. (1987) and Jenkins et al. (1988).

Obviously, the use of PA in a cow-calf operation of the Midwest will require additional research to answer the questions of reproductive functionality and longevity of the female. This research project was undertaken to evaluate the performance, reproductive traits, milk potential, and calf performance of dams exposed prenatally to testosterone propionate (TP).

PROCEDURE

Thirty-seven PA heifers and 50 control heifers born in the spring of 1989 either at the Orr Beef Research Center or Dixon Springs Agricultural Center (DSAC) were used for the study. Heifers located at the Orr Center were of a Simmental base and those at DSAC were of an Angus/Hereford base.

PA heifers were born to dams implanted with four TP implants inserted subcutaneously behind the shoulder and over the dorsal aspect of the rib cage of the pregnant cow. These implants were 15 cm long, contained approximately 2.25 g TP, and provided an average secretion rate of 37.8 mg TP per day (Kesler, 1987).

Within 24 h of birth, heifers used in the study were measured for birth weight and evaluated for calving ease using a five point scale (1 = no assistance required, 2 = slight mechanical assistance required, 3 = mechanical assistance required, 4 = caesarean section, 5 = abnormal presentation). Heifers were run on pasture with dam until weaning at approximately 216 d of age. Weights of the Orr Center cattle and pelvic measurements (Rice and Wiltbank, 1972) of all cattle were taken at 457 and 506 d of age, respectively prior to breeding. Cattle were initially synchronized utilizing the commercial product Syncro-Mate B. Those determined to be open following the first insemination, were reinseminated approximately 30 d later. Any remaining open heifers were pasture bred by natural service.

Calves of PA and control heifers were similarly evaluated for birth weight and calving ease. In addition, the percent assistance required and percent mortality recorded. Heifers and calves at DSAC were run on a Tall Fescue based pasture, those at the Orr Center were run on an orchardgrass/alfalfa based pasture until weaning at 227 d of age.

At DSAC, 34 heifers (half PA and half control) were selected at random to collect milk production data. These heifers were initially milked at six weeks \pm 3 d postpartum (March 5 to April 11, 1991). Second and third milkings occurred on May 16, and July 18, 1991, regardless of days postpartum. Prior to milking, calves were removed from dams for a period of 6 h, allowed to nurse dams dry, and subsequently removed until after milking the following day. Immediately prior to milking, heifers were injected intramuscularly with 100 U.S.P. units of oxytocin to stimulate milk letdown. Dams were then milked by machine. The milk was weighed and two representative samples (28 g) preserved with 2-bromo-2-nitropropane-1,3 diol were saved for subsequent compositional analysis of protein, fat, and solids non-fat (Golding, 1959).

Statistically, the data was analyzed as a completely randomized design (SAS, 1988). Known sources of variation such as sire of the heifer or calf, sex of calf, and location were removed to test the effects of PA upon the dependent variables. Weights were additionally adjusted for age and birth weight using covariate analysis. In the tables, least squares means are reported with significance between treatment means determined by a protected F-test. In the event of unequal standard errors, the largest standard error of the treatment means being compared is reported.

RESULTS AND DISCUSSION

Calving, growth, and reproductive characteristics of PA and control heifers are shown in Table 1. PA heifers born to TP implanted dams exhibit similar ($P > .50$) birth weights and calving ease scores as controls. There also appeared to be no difference in growth performance through weaning. Similarly, DeHaan et al. (1990a) found no differences in the birth or weaning weights of androgenized and control heifers. However, many researchers have reported increased gains of PA heifers compared to controls when greater than one year of age (Hamernik et al., 1987) or when fed a feedlot ration (DeHaan et al., 1988). In this particular study, however, increased performance potential of the PA heifers at greater

than one year of age was not exhibited. Perhaps this was a function of the heifers grazing lower energy feedstuffs and raised for the purpose of calf production.

At an average age of 506 d, two weeks prior to breeding, heifers were measured for pelvic size. Since an androgenization by location interaction was significant, these values are reported independently for the DSAC and Orr Center stations in Table 1. In cattle of predominantly Angus/Hereford breeding (DSAC), control heifers exhibited 12 cm² larger ($P < .05$) pelvic areas. Since birth weights of calves born to PA and control heifers were similar (Table 2), the smaller pelvic openings could attribute to the apparent increase in calving difficulty ($P < .05$), required intervention at calving ($P < .15$), and mortality rates ($P < .05$) of calves born to PA heifers (Table 2).

Reproductive characteristics of heifers are shown in Table 1. PA heifers actually showed a trend ($P < .20$) to settle more easily upon the initial insemination. This is in contrast to the findings of Clarke and Sacramuzzi (1978) who found testosterone to promote masculine behavior and inhibit oestrus. However, Heitzman et al. (1979) evaluated heifers implanted with trenbolone acetate prepuberally and found conception rates to be normal, but that an increased incidence of dystocia was apparent as shown in this study.

After removing variation due to calving ease score, 60% of control heifers rebred compared to only 35% ($P < .05$) of the PA heifers. Overall, conception rates are low due to cows becoming underconditioned, but the controls adapted to adverse conditions more readily than the androgenized heifers. In addition, there appears to be visual evidence of vaginal tearing in some of the PA heifers indicating that greater stress upon the reproductive organs occurs at parturition amongst the PA females which could account partially for the low rebreeding rates.

Four percent fat corrected milk yields (NRC, 1989) and composition for three different milkings are reported in Table 3. No significant differences existed, although controls numerically produced more milk than the PA heifers. All cattle evaluated for milk production were run on Tall Fescue based pastures through the summer and it is possible that energy intake was limiting and did not allow for total milk production potential of the heifers to be expressed.

IMPLICATIONS

Although recent research has indicated that PA may be a potential means of increasing production efficiency of beef, this particular study found few differences in the growth and milking characteristics of grazing PA and control heifers. Reproductively, there appeared to be little difference in the first AI conception rates. Rebreeding of PA females appears to be a significant problem for producers. Thus, if the proposed advantages of PA for increased growth and milk production exist, a greater plane of nutrition may be necessary for its expression. In addition, greater management skills at calving will be necessary and the PA females should be used in a single calving heifer system where rebreeding problems would be of little concern.

LITERATURE CITED

- Clarke, I. J. and R. J. Scaramuzzi. 1978. Sexual behavior and LH secretion in spayed androgenized ewes after a single injection of testosterone or oestradiol-17 β . *J. Reprod. Fert.* 52:313.
- DeHaan, K. C., L. L. Berger, D. J. Kesler, F. K. McKeith, D. L. Thomas, and T. G. Nash. 1987. Effect of prenatal androgenization on lamb performance, carcass composition, and reproductive function. *J. Anim. Sci.* 65:1465.
- DeHaan, K. C., L. L. Berger, D. J. Kesler, F. K. McKeith, D. B. Faulkner, and G. F. Cmarik. 1988. Effect of prenatal androgenization on growth performance and carcass characteristics of steers and heifers. *J. Anim. Sci.* 66:1864.
- DeHaan, K. C., L. L. Berger, D. J. Kesler, F. K. McKeith, D. B. Faulkner, G. F. Cmarik, and R. J. Favero. 1990a. Effects of prenatal testosterone treatment and postnatal steroid implantation on growth performance and carcass traits of heifers and steers. *J. Anim. Sci.* 68:2198.
- Golding, N. S. 1959. A solids-not-fat test for milk using density plastic beads as hydrometers. *J. Dairy Sci.* 42:899 (Abstr.).
- Hamernik, D. L., S. Y. McFarland, D. de Avila, S. R. Becker, and J. J. Reeves.

1987. Endocrine and body growth traits in heifers exposed to testosterone-propionate during early fetal development. J. Anim. Sci. 64:1858.

Heitzman, R. J., D. J. Harwood, R. M. Kay, W. Little, C. B. Mallinson, and I. P. Reynolds. 1979. effects of implanting prepuberal dairy heifers with anaboloic steroids on hormonal status, puberty, and parturition. J. Anim. Sci. 48:859.

Jansson, J., S. Ekberg., O. Isaksson, A. Mode, and J. gustafsson. 1985. Imprinting of growth hormone secretion, body growth, and hepatic steroid metabolism by neonatal testosterone. Endocrinology 117:1881.

Jenkins, T. G., J. J. Ford, and J. Klindt. 1988. Postweaning growth, feed efficiency, and chemical composition of sheep as affected by prenatal and postnatal testosterone. J. Anim. Sci. 66:1179.

Kesler, D. J. 1987. Novel approaches and applications of steroid hormone delivery via polydimethylsiloxane. Proc. Am. Chem. Soc. Div. Poly. Mater. Sci. Eng. 57:408.

Klindt, J., T. G. Jenkins, and J. J. Ford. 1986. Effect of prenatal androgen exposure on growth and the secretion of growth hormone (GH) and prolactin (PRL). J. Anim. sci. 63(Suppl. 1):230 (Abstr.).

NRC. 1989. Nutrient Requirements of Dairy Cattle (6th Ed.). National Academy Press, Washington, DC.

Rice, L. E. and J. N. Wiltbank. 1972. factors affecting dystocia in beef heifers. J. Amer. Vet. Med. Assoc. 161:1348.

SAS. 1988. SAS User's Guide: Statistics. SAS Inst., Inc., Cary, NC.

Slob, A. K. and J. J. van der Werff ten Bosch. 1975. Sex differences in body growth in the rat. Physiol. Behav. 14:353.

TABLE 1. EFFECT OF PRENATAL ANDROGENIZATION (PA) UPON THE BIRTH, GROWTH, AND REPRODUCTIVE CHARACTERISTICS OF HEIFERS

Item	No.	PA	Control	SEM ^a	Treatment effect ^b
Birth wt, kg	87	35.7	35.8	1.1	.9421
Calving ease ^c	87	1.34	1.38	.18	.8533
Weaning wt, kg	86	206.0	210.4	5.2	.4594
Yearling wt, kg	25	430.5	451.8	31.2	.5816
Pelvic size, cm ² @ DSAC ^d	61	188.36	200.54	3.85	.0076
Pelvic size, cm ² @ Orr Center ^d	26	233.30	232.28	6.28	.8954
First AI conception rate - 1990, %	87	58.23	41.67	8.55	.1695
First AI conception rate - 1991, %	86	11.73	17.59	11.16	.5863
Pregnancy rate 1991, %	86	60.48	35.02	12.56	.0381
Postpartum interval, d	32	95	93	10	.8911
Calving interval, d	32	376	378	10	.8911

^aGreatest standard error of treatment means (SEM) reported.

^bProbability of observing a greater F-value.

^c1=no assistance, 2=slight mechanical assistance, 3=mechanical assistance, 4=C-section, 5=abnormal presentation.

^dDSAC and Orr Center pelvic measurements reported separately due to a treatment by location interaction.

TABLE 2. PERFORMANCE OF CALVES BORN TO PRENATALLY ANDROGENIZED (PA) AND CONTROL FEMALES

Item	No.	PA	Control	SEM ^a	Treatment effect ^b
No. of animals	87	37	50		
Birth wt., kg	86	33.5	33.9	.9	.6860
Calving ease ^c	87	2.08	1.63	.18	.0438
Assistance ^d , %	87	56.96	39.89	9.76	.1455
Mortality, %	87	16.70	.64	6.41	.0383
Weaning wt. ^e , kg	73	202.9	198.6	6.6	.5371

^aGreatest standard error of treatment means (SEM) reported.

^bProbability of observing a greater F-value.

^c1=no assistance, 2=slight mechanical assistance, 3=mechanical assistance, 4=C-section, 5=abnormal presentation.

^dPercentage of calves requiring assistance at parturition.

^eCalves weaned at an average age of 227 d adjusted to an equivalent birth date and birth weight by covariate analysis.

TABLE 3. EFFECT OF PRENATAL ANDROGENIZATION (PA) UPON CALF WEANING WEIGHTS, MILK YIELD, AND MILK COMPOSITION OF ANGUS/HEREFORD HEIFERS GRAZING TALL FESCUE

Item	PA	Control	SEM ^a	Treatment effect ^b
No. of animals	17	17		
Calf weaning wt., kg	162.1	162.5	10.6	.9676
1st Milking 4% FCM ^c , kg	7.66	8.80	.77	.1690
1st Milking protein, %	3.05	3.09	.09	.6151
1st Milking protein, kg	.23	.26	.03	.4793
1st Milking fat, %	4.21	4.38	.36	.6456
1st Milking fat, kg	.31	.37	.03	.1074
1st Milking SNF ^d , %	8.30	8.54	.15	.1312
1st Milking SNF, kg	.63	.70	.07	.2876
2nd Milking 4% FCM ^c , kg	4.67	4.90	.88	.7938
2nd Milking protein, %	3.35	3.44	.11	.4270
2nd Milking protein, kg	.14	.14	.02	.9107
2nd Milking fat, %	4.04	4.88	.62	.1993
2nd Milking fat, kg	.19	.21	.04	.6579
2nd Milking SNF ^d , %	8.42	8.23	.17	.2881
2nd Milking SNF, kg	.37	.36	.06	.8359
3rd Milking 4% FCM ^c , kg	2.77	2.89	.39	.7778
3rd Milking protein, %	3.06	3.03	.06	.5350
3rd Milking protein, kg	.09	.09	.01	.7385
3rd Milking fat, %	3.92	3.44	.38	.2387
3rd Milking fat, kg	.11	.11	.02	.9967
3rd Milking SNF ^d , %	7.78	7.77	.09	.9118
3rd Milking SNF, kg	.22	.24	.03	.4093

^aGreatest standard error of treatment means (SEM) reported.

^bProbability of observing a greater F-value.

^c24 h 4% fat corrected milk yield (NRC, 1989).

^dSolids non-fat (Golding, 1959).

EFFECTS OF MELENGESTROL ACETATE (MGA) AND SYNOVEX H UPON THE GROWTH PERFORMANCE AND CARCASS TRAITS OF FIRST-CALF HEIFERS FOLLOWING EARLY WEANING

B. A. Reiling, L. L. Berger, D. B. Faulkner, and T. G. Nash

SUMMARY

Forty-eight Simmental cross first-calf heifers had their calves removed at approximately 120 d of age and were placed on a high energy diet to evaluate the effects of Melengestrol Acetate (MGA) and Synovex H implants (200 mg testosterone propionate and 20 mg estradiol benzoate) upon performance and carcass attributes. The cattle were randomly allotted and assigned to pens equipped with pinpointter or "dummy" feeding devices for measurement of individual feed intakes. Cattle were rotated among pens on 2-wk intervals and were weighed every 28 d. When cattle were determined to possess approximately .8 cm (.3 in) subcutaneous fat cover, cattle were weighed following a 12 h fast and shipped to a commercial packing plant. Twenty-four h post-mortem, carcass data was collected by University of Illinois personnel. Average gains of all heifers were high (1.73 kg/d or 3.81 lbs/d), however, heifers were slow to fatten during the 100 d feeding period. MGA appeared to have little effect upon performance or carcass traits. Synovex H implants, however, appeared to enhance average daily gains and feed efficiency of these older heifers by approximately 10%. Implanted cattle also tended to have more advanced overall maturity scores. Overall, 11 of 45 heiferette carcasses were designated as hard bone (C maturity) and received discounts of \$12 to \$24/cwt of carcass weight. However, the average price was still approximately \$12/cwt greater, on a live basis, than the price received for cull cows.

INTRODUCTION

The traditional dogma regarding increased efficiency of cow-calf production has been to maximize longevity of the reproductive unit within the herd. However, recent research has indicated that single calving heifer (SCH) systems may actually improve efficiency of production as the roles of reproduction and meat production are combined into one unit (Taylor et al., 1985).

Maximal profitability with a SCH system, however, is contingent upon the heifers being slaughtered by thirty months of age so heiferette carcasses may qualify for choice and select beef prices (Brethour and Jaeger, 1989). It must be recognized, however, that carcass maturity is not based upon actual age of the animal, but is subjectively determined by the USDA grader after evaluating such factors as bone ossification and fusion, redness of ribs, and lean color and texture. Factors which may advance the physiological maturity of carcasses would require the heifers being slaughtered at even younger ages. Thus, thirty months is only a guideline for cattle producers.

A majority of research regarding utilization of Melengestrol acetate (MGA) and Synovex H (200 mg testosterone propionate and 20 mg estradiol benzoate) implants has focused upon young feedlot heifers. Thus the objective of this study was to evaluate the effects of MGA and Synovex H implants upon the growth and carcass traits of early weaned first-calf heifers.

PROCEDURE

Forty-eight Simmental cross first-calf heifers from the Orr Beef Cattle Research Center had their calves early weaned at approximately 120 days and were transported to the Urbana Beef Research Center. Following a 12 h fast, these heiferettes were weighed and allotted at random to one of four treatment groups. Half of the heifers were implanted with Synovex H on d 1 of the feedlot trial. Half of the heifers were also fed .35 mg MGA per head per day in the feed throughout the trial.

Cattle were placed in pens equipped with either Pinpointer 4000B feeding devices or "dummy" pinpointers. Cattle were rotated between the two types of feeders at 2-wk intervals. Individual feed intakes were recorded using the pinpointer feeders, while pen feed intakes were recorded from the "dummy" feeders during the 2-wk period. Individual feed intakes from "dummy" feeders were estimated by calculating the individual's percent intake of the total intake from the pinpointer feeders. This percentage was then used to calculate an approximate individual intake from the "dummy" feeders.

Heifers were fed a 12% crude protein (CP) diet formulated to meet or

exceed NRC (1984) requirements for CP, Ca, P, K, trace minerals, and vitamins. Cattle were weighed every 28 d throughout the trial.

A subcutaneous fat thickness of .8 cm was selected as an experimental end point. Fat thickness was monitored using a real-time linear array ultrasound instrument as cattle approached market readiness. Termination weights were recorded following a 12 h fast and cattle transported to a commercial packing plant for slaughter. At 24 h postmortem, carcasses were evaluated for quality and yield grade traits by University of Illinois personnel.

All data was analyzed as a 2 X 2 factorial design. Because individual data was collected on each animal for all traits evaluated, the individual animal served as the experimental unit for all analyses. Least square means were separated by the LSD procedure protected by a significant ($P < .10$) F-test. All statistical analyses were performed using the GLM procedure of SAS (1988).

RESULTS AND DISCUSSION

Interactions were not significant and thus only main effects of MGA and Synovex H implants are shown in the tables. Additionally, only 45 heifers were actually used in the study as three had to be dismissed from the trial as they had difficulty adjusting to the pinpoint feeding devices.

MGA is fed to eliminate the onset of estrus and bulling of feedlot heifers and thus would be expected to improve average daily dry matter intake, average daily gain, and feed efficiency. However, in this study, MGA appeared to have little effect upon performance attributes (Table 1). It should be noted, however, that average daily gains for the 100 d feeding period were relatively high for all individuals (1.73 kg/d or 3.81 lbs/d). Much of this performance could be attributed to the fact heifers were in thin condition at the onset of the trial. Heifers continued to gain, but did not readily deposit fat and were consequently slaughtered at only .8 cm (.3 in) subcutaneous fat cover to minimize the potential number of hard bone (C maturity) carcasses.

The effects of Synovex H upon performance traits of the first-calf heifers is shown in Table 2. As found with younger feedlot cattle, the implant improved average daily gain approximately 10% ($P < .10$). Dry matter

intakes were similar ($P > .50$) for implanted and non-implanted heifers, thus overall feed efficiency of Synovex implanted heifers was 10% greater ($P < .07$) than controls.

The effects of MGA and Synovex H upon carcass traits are shown in Tables 3 and 4, respectively. MGA did not appear to significantly alter carcass composition. MGA also did not affect physiological maturity scores of bone or lean tissue. This is of practical importance for a system dependent upon the maintenance of youthful appearing carcasses.

As shown in Table 4, the Synovex H implant appeared to numerically elevate maturity scores of lean (darker) and bone (greater ossification). However, only when both scores were combined for an overall maturity was significance approached ($P < .16$). Waggoner et al. (1990) also found implanted single calf heifers to possess a greater concentration of calcium in the cartilagenous buttons as compared to non-implanted single calf heifers or open heifers indicating greater physiological maturity of the heiferettes implanted with Synovex H.

Overall, the heifers were approximately 30 months of age at time of slaughter. Eleven carcasses were subjectively evaluated as C° maturity (hard bone) and thus were ineligible for the choice and select grades of beef. Five of the eleven heifers had been exposed to MGA and seven were implanted. For these physiologically older carcasses, a \$12 to \$24 per cwt of carcass weight discount was applied.

IMPLICATIONS

Early weaned first-calf heifers of Simmental breeding will grow at extremely fast rates (1.73 kg /d or 3.81 lbs/d) when placed on a high energy finishing ration, however, due to physical size appear not to fatten to levels of typical market readiness (1.0 cm or .4 in fat cover) by thirty months of age. MGA may be fed and appears to have no detrimental effect upon carcass maturity or composition. However in this study, MGA produced no benefits in performance of these older heifers. Synovex H did improve average daily gain and feed efficiency by approximately 10% as compared to non-implanted controls. However, the Synovex H implant also appeared to advance the overall maturity scores of heiferette carcasses. Thus, for the implant to be beneficial, the increased gains must offset potentially increased maturity scores. In this study, the improved

performance would have more than offset the affects of increased maturity.

LITERATURE CITED

- Brethour, J. R. and J. R. Jaeger. 1989. The single-calf heifer system. Kansas Agric. Sta. Rep. of Progress 570.
- NRC. 1984. Nutrient Requirements of Beef Cattle (6th Ed.). National Academy Press, Washington, DC.
- SAS. 1988. SAS User's Guide: Statistics. SAS Inst., Inc., Cary, NC.
- Taylor, C. S., A. J. Moore, R. B. Thieesen, and C. M. Bailey. 1985. Efficiency of feed utilization in traditional and sex-controlled systems of beef production. Anim. Prod. 40:401.
- Waggoner, A. W., M. E. Dikeman, J. R. Brethour, and K. E. Kemp. 1990. Performance, carcass, cartilage calcium, sensory, and collagen traits of longissimus muscles of open versus 30-month-old heifers that produced one calf. J. Anim. Sci. 68:2380.

TABLE 1. EFFECT OF MGA^a UPON PERFORMANCE TRAITS OF FIRST-CALF HEIFERS AFTER EARLY WEANING

Item	No MGA	MGA	SEM ^b	Treatment Effect ^c
No. of animals	23	22		
On-test wt, kg	418.4	421.9	9.3	.7877
Days on feed	99	96	4	.5415
DM feed intake, kg	11.80	11.31	.29	.2318
Daily gain, kg/d	1.77	1.70	.07	.5262
Gain/Feed	.150	.150	.005	.9961
Off-test wt, kg	590.0	583.2	12.2	.6953

^aMelengestrol Acetate.

^bGreatest standard error of treatment means (SEM) reported.

^cProbability of observing a greater F-value.

TABLE 2. EFFECTS OF SYNOVEX H^a IMPLANTS UPON PERFORMANCE TRAITS OF FIRST-CALF HEIFERS AFTER EARLY WEANING

Item	No Synovex	Synovex	SEM ^b	Treatment Effect ^c
No. of animals	23	22		
On-test wt, kg	419.2	421.1	9.3	.8859
Days on feed	98	98	4	.9615
DM feed intake, kg	11.49	11.62	.29	.7427
Daily gain, kg/d	1.65	1.82	.07	.0885
Gain/Feed	.143	.158	.005	.0639
Off-test wt, kg	577.8	595.4	12.2	.3074

^a200 mg Testosterone propionate and 20 mg estradiol benzoate.

^bGreatest standard error of treatment means (SEM) reported.

^cProbability of observing a greater F-value.

TABLE 3. EFFECT OF MGA^a UPON CARCASS TRAITS OF FIRST-CALF HEIFERS AFTER EARLY WEANING

Item	No MGA	MGA	SEM ^b	Treatment Effect ^c
No. of animals	23	22		
Live wt, kg	590.0	583.2	12.2	.6953
Hot carcass wt, kg	343.0	352.2	8.3	.4375
Dressing percent	58.16	60.31	.61	.0154
Adj. fat thickness, cm	.82	.83	.06	.9729
Ribeye area, cm ²	86.65	90.50	1.81	.1370
KPH, %	1.93	2.14	.09	.1134
Yield grade ^d	2.27	2.20	.12	.6640
Overall maturity ^e	238	235	12	.8379
Bone maturity ^e	239	230	13	.6696
Lean maturity ^e	220	231	13	.5540
Marbling score ^f	1015	1032	11	.2709

^aMelengestrol Acetate.

^bGreatest standard error of treatment means (SEM) reported.

^cProbability of observing a greater F-value.

^dYield grade = $2.5 + (2.5 \times \text{adj. fat thickness}) + (.0038 \times \text{hot carcass wt.}) + (.2 \times \text{KPH}) - (.32 \times \text{ribeye area})$.

^e100=A⁰, 200=B⁰, 300=C⁰.

^f900=slight⁰, 1000=small⁰, 1100=modest⁰.

TABLE 4. EFFECT OF SYNOVEX H^a IMPLANTS UPON CARCASS TRAITS OF FIRST-CALF HEIFERS AFTER EARLY WEANING

Item	No		SEM ^b	Treatment
	Synovex	Synovex		Effect ^c
No. of animals	23	22		
Live wt, kg	577.8	595.4	12.2	.3074
Hot carcass wt, kg	341.2	354.0	8.3	.2812
Dressing percent	59.03	59.43	.61	.6364
Adj. fat thickness, cm	.81	.84	.06	.7602
Ribeye area, cm ²	86.65	90.50	1.81	.1370
KPH, %	2.05	2.02	.09	.8452
Yield grade ^d	2.27	2.21	.12	.6967
Overall maturity ^e	225	248	12	.1546
Bone maturity ^e	225	244	13	.3383
Lean maturity ^e	214	237	13	.2258
Marbling Score ^f	1026	1021	11	.7826

^a200 mg testosterone propionate and 20 mg estradiol benzoate.

^bGreatest standard error of treatment means (SEM) reported.

^cProbability of observing a greater F-value.

^dYield grade = 2.5 + (2.5 X adj. fat thickness) + (.0038 X hot carcass wt.) + (.2 X KPH) - (.32 X ribeye area).

^e100=A⁰, 200=B⁰, 300=C⁰.

^f900=slight⁰, 1000=small⁰, 1100=modest⁰.

GROWTH PERFORMANCE, CARCASS TRAITS, AND SENSORY ATTRIBUTES OF OPEN HEIFERS AS AFFECTED BY AGE AND PRENATAL ANDROGENIZATION

B. A. Reiling, L. L. Berger, F. K. McKeith, D. B. Faulkner, and T. G. Nash

SUMMARY

Sixteen prenatally androgenized (PA) open first-calf heifers, 16 control open first-calf heifers, 8 PA open virgin heifers, and 8 open control heifers were randomly allotted to four pens in a 2 X 2 factorial design. All pens were equipped with pinpointer feeding devices for the collection of individual feed intake data. PA appeared to have no effect upon performance. First-calf open heifers did gain faster ($P < .05$) and more efficiently ($P < .05$) than virgin open heifers. Carcass traits of PA heifers did not differ from those of controls except for greater physiological maturity (darker color) of the lean. Age also resulted in greater maturity, however, there were no differences among sensory attributes due to PA or age as determined by an experienced six member taste panel.

INTRODUCTION

Recent research conducted at the University of Illinois has indicated that alteration of the prenatal steroid environment of heifers may result in increased performance and carcass merit relative to controls. Testosterone propionate (TP) administered prenatally between d 40 and 80 of gestation has produced heifer calves that gain 10.4% faster with 12.9% greater efficiency than control contemporaries when marketed at an average subcutaneous fat thickness of 1.2 cm (DeHaan et al., 1990). Prenatal testosterone treatments also resulted in carcasses having larger ribeye areas, less internal fat, and more desirable final yield grades. Proximate composition of the 9-10-11 rib section has shown carcasses of prenatally androgenized heifers to possess less ($P < .07$) lipid than control heifers when slaughtered at a constant weight (DeHaan et al., 1988).

These studies exemplified the typical feedlot situation utilizing young, virgin heifers that were weaned and immediately placed upon full feed for fattening and marketing at approximately 18 months of age. However, single calving heifer (SCH) systems have been shown to increase efficiency of beef production compared to the typical cow-calf, feedlot

operations by combining reproduction and meat production into one system (Taylor et al., 1985). The SCH system involves retaining surplus heifers, breeding them to produce one calf, and finishing in the feedlot shortly after parturition. As a result, heifers in a SCH system are approximately 28 to 30 months of age at slaughter.

Little is known regarding the usefulness of prenatal androgenization (PA) in terms of increased performance and carcass merit of these older heiferettes. Thus, this study was conducted to evaluate the effects of prenatal testosterone exposure on feedlot performance, carcass traits, and sensory attributes of older heifers slaughtered at approximately 36 months of age compared with yearling open heifers slaughtered at approximately 24 months of age.

PROCEDURE

Dams of prenatally androgenized open heifers utilized in the study were implanted with four TP implants on approximately d 80 of pregnancy. The implants were made of a medical grade silastic tubing with an inside diameter of .635 cm and an outside diameter of .935 cm, were 15 cm long, contained approximately 2.25 g TP, and provided an average secretion rate of 37.8 mg TP per day (Kesler, 1987). The implants were subcutaneously inserted behind the shoulder and over the dorsal aspect of the rib cage of the pregnant cow and removed approximately three weeks prior to calving.

Following the 1991 breeding season, 16 prenatally androgenized open first calf heifers, 16 control open first-calf heifers, 8 prenatally androgenized open virgin heifers, and 8 control open virgin heifers were transported to the University of Illinois Urbana Beef Research Center. Following a 12 h fast, these cattle were weighed and allotted to one of 4 pens equipped with Pinpointer 4000B feeding devices to allow for the collection of individual feed intakes. All heifers were implanted with Synovex H (200 mg TP and 20 mg estradiol benzoate) at the start of the trial.

Heifers were fed a 12% crude protein (CP) diet consisting of whole high-moisture corn and ammoniated corn cobs (Table 1) supplemented with soybean meal and urea (Table 1) for the entire feeding period. The finishing diet was balanced to meet or exceed the NRC (1984) requirements for CP, Ca, P, K, trace minerals, and vitamins. Cattle were weighed every 28 d throughout the feeding trial.

A subcutaneous fat cover of 1.1 cm was utilized as the experimental end point as determined by the use of a real-time linear array ultrasound instrument. Upon termination, cattle were again fasted for 12 h prior to a final weight being taken. Cattle were then slaughtered either at the University of Illinois Meat Laboratory or at a commercial slaughter plant. At 24 h postmortem, carcasses were evaluated for quality and yield grade traits by trained personnel.

Longissimus dorsi steaks were collected from each of 24 different carcasses representing each treatment subgroup for use in subsequent sensory and shear analysis. These steaks were aged for a period of 7 d, cooked to an internal temperature of 70° C, and served warm to a 6 member experienced taste panel. Steaks were evaluated for tenderness, juiciness, beef flavor, presence of off flavors, and overall palatability by the panelists using a 15 cm continuous scale. After evaluating the sample, the panelist placed a mark upon the 15 cm line which represented his/her assessment of the attribute measured from one extreme (dry) to the other (juicy). The distances of these marks were then measured and used as the value for statistical analysis. In addition, Warner-Bratzler (WB) shear tests were performed as an objective measurement of tenderness using an Instron Universal Testing Machine (model 1132).

All data was analyzed as a 2 X 2 factorial design with 2 levels of age (first-calf heifers vs virgin heifers) and 2 levels of androgenization (androgenized vs control). Because individual data was collected on each animal for all traits evaluated, the individual animal served as the experimental unit for all analyses. Least square means were separated by the LSD procedure protected by a significant ($P < .05$) F-test. All statistical analyses were performed using the GLM procedure of SAS (1988).

RESULTS AND DISCUSSION

All interactions were not significant and thus only the main effects of PA and age are shown in the tables. As shown in Table 2, PA had little effect upon dry matter intake, daily gain, and efficiency. Table 3 shows the effects of age upon performance. First-calf open heifers were fed an average 7 d longer than yearling virgin heifers to obtain the desired fat thickness. Despite the additional feeding, first-calf open heifers

exhibited higher ($P < .05$) daily gains and gain/feed ratios resulting in heavier ($P < .05$) off-test weights. Similar findings were reported by Waggoner et al. (1990) where two-year old open heifers gained 1.3 kg/d compared to one-year old open heifers which gained 1.1 kg/d for a 112 to 137 d feeding period.

Carcass data of PA and control heifers is shown in Table 4. The PA heifers tended to become slightly fatter than our objective endpoint of 1.1 cm subcutaneous fat cover, however, no differences due to PA were evident among the factors related to yield of red meat. In terms of quality, PA had no effect ($P > .20$) upon the physiological maturity of the skeleton, but did have a negative impact ($P < .05$) upon the lean maturity of carcasses resulting in darker colored meat as compared to controls, which could hinder retail acceptance of such product.

The effects of age upon carcass traits is shown in Table 5. First-calf open heifers had heavier hot carcass weights. Otherwise, no differences in fat, ribeye area, internal fat, or final yield grades existed. As is well established, physiological skeletal and lean maturity of first-calf heifers was much more advanced than the yearling open heifers. However, despite these tendencies for the PA and older heifers to be more physiologically mature, all retail sensory product was deemed acceptable and there were no differences among treatments for juiciness, tenderness, flavor, or overall palatability (Tables 6 and 7).

IMPLICATIONS

Although PA has been shown to be effective in improving performance and carcass merit of young feedlot heifers, PA did not appear to be beneficial for improvement of performance in older heiferettes which would be more typical of those used in a SCH system. However, first-calf open heifers can be fed to produce acceptable, choice beef for the retail counter with few discounts.

LITERATURE CITED

- DeHaan, K. C., L. L. Berger, D. J. Kesler, F. K. McKeith, D. B. Faulkner, and G. F. Cmarik. 1988. Effect of prenatal androgenization on growth performance and carcass characteristics of steers and heifers. *J. Anim. Sci.* 66:1864.
- DeHaan, K. C., L. L. Berger, D. J. Kesler, F. K. McKeith, D. B. Faulkner, G. F. Cmarik, and R. J. Favero. 1990. Effects of prenatal testosterone treatment and postnatal steroid implantation on growth performance and carcass traits of heifers and steers. *J. Anim. Sci.* 68:2198.
- Kesler, D. J. 1987. Novel approaches and applications of steroid hormone delivery via polydimethylsiloxane. *Proc. Am. Chem. Soc. Div. Poly. Mater. Sci. Eng.* 57:408.
- NRC. 1984. *Nutrient Requirements of beef Cattle* (6th Ed.). National Academy Press, Washington, DC.
- SAS. 1988. *SAS User's Guide: Statistics*. SAS Inst., Inc., Cary, NC.
- Taylor, C. S., A. J. Moore, R. B. Thieesen, and C. M. Bailey. 1985. Efficiency of feed utilization in traditional and sex-controlled systems of beef production. *Anim. Prod.* 40:401.
- Waggoner, A. W., M. E. Dikeman, J. R. Brethour, and K. E. Kemp. 1990. Performance, carcass, cartilage calcium, sensory, and collagen traits of longissimus muscles of open versus 30-month-old heifers that produced one calf. *J. Anim. Sci.* 68:2380.

TABLE 1. COMPOSITION OF DIETS FED^a

Ingredient	Days			
	1 - 5	6 - 10	11 - 15	>16
Ammoniated corn cobs	45	35	25	15
Corn, whole (high moisture)	42	52	62	72
Molasses	3	3	3	3
Pelleted Supplement	10	10	10	10

^aPercent of diet (DM basis).

TABLE 2. EFFECT OF PRENATAL ANDROGENIZATION (PA) UPON PERFORMANCE TRAITS OF OPEN HEIFERS

Item	PA	Control	SEM	Treatment
				Effect ^a
No. of animals	24	24		
On-test wt, kg	403.6	388.7	9.8	.2900
Days on feed	87	85	2	.5144
DM feed intake, kg	13.23	12.97	.40	.6570
Daily gain, kg/d	1.67	1.67	.08	.9890
Gain/Feed	.128	.130	.006	.7762
Off-test wt, kg	549.3	531.8	12.4	.3263

^aProbability of observing a greater F-value.

TABLE 3. EFFECT OF CALVING UPON PERFORMANCE TRAITS OF OPEN HEIFERS

Item	Virgin Heifers	First-calf Heifers	SEM ^a	Treatment Effect ^b
No. of animals	16	32		
On-test wt, kg	391.7	400.6	11.4	.5275
Days on feed	83	90	2	.0216
DM feed intake, kg	13.05	13.17	.46	.8309
Daily gain, kg/d	1.54	1.81	.09	.0211
Gain/Feed	.119	.138	.007	.0375
Off-test wt, kg	518.7	562.4	14.4	.0169

^aGreatest standard error of treatment means (SEM) reported.

^bProbability of observing a greater F-value.

TABLE 4. EFFECT OF PRENATAL ANDROGENIZATION (PA) UPON CARCASS TRAITS OF OPEN HEIFERS

Item	PA	Control	SEM	Treatment Effect ^a
No. of animals	24	24		
Live wt, kg	549.3	531.8	12.4	.3263
Hot carcass wt, kg	330.7	324.1	7.3	.5261
Dressing percent	60.27	61.01	.46	.2622
Adj. fat thickness, cm	1.21	1.08	.06	.1154
Ribeye area, cm ²	83.67	82.70	1.79	.7034
KPH, %	1.31	1.45	.08	.2013
Yield grade ^b	2.58	2.47	.10	.4574
Overall maturity ^c	210	194	10	.2302
Bone maturity ^c	220	209	11	.4766
Lean maturity ^c	204	176	8	.0250
Marbling Score ^d	1018	1050	17	.1934

^aProbability of observing a greater F-value.

^bYield grade = 2.5 + (2.5 X adj. fat thickness) + (.0038 X hot carcass wt.) + (.2 X KPH) - (.32 X ribeye area).

^c100=A⁰, 200=B⁰, 300=C⁰.

^d900=slight⁰, 1000=small⁰, 1100=modest⁰.

TABLE 5. EFFECT OF CALVING UPON CARCASS TRAITS OF OPEN HEIFERS

Item	Virgin Heifers	First-calf Heifers	SEM ^a	Treatment Effect ^b
No. of animals	16	32		
Live wt, kg	518.7	562.4	14.3	.0169
Hot carcass wt, kg	316.4	338.5	8.5	.0385
Dressing percent	61.03	60.25	.53	.2366
Adj. fat thickness, cm	1.19	1.10	.07	.2690
Ribeye area, cm ²	81.45	84.92	2.06	.1766
KPH, %	1.28	1.48	.09	.0676
Yield grade ^c	2.53	2.50	.12	.7961
Overall maturity ^d	169	235	11	.0001
Bone maturity ^d	174	255	13	.0001
Lean maturity ^d	164	217	10	.0001
Marbling Score ^e	1041	1028	20	.6017

^aGreatest standard error of treatment means (SEM) reported.

^bProbability of observing a greater F-value.

^cYield grade = $2.5 + (2.5 \times \text{adj. fat thickness}) + (.0038 \times \text{hot carcass wt.}) + (.2 \times \text{KPH}) - (.32 \times \text{ribeye area})$.

^d100=A⁰, 200=B⁰, 300=C⁰.

^e900=slight⁰, 1000=small⁰, 1100=modest⁰.

TABLE 6. EFFECT OF PRENATAL ANDROGENIZATION (PA) UPON SENSORY ATTRIBUTES OF OPEN HEIFERS

Item	PA	Control	SEM	Treatment Effect ^a
No. of animals	12	12		
Juiciness ^b	9.77	9.75	.40	.9793
Tenderness ^b	9.00	9.21	.47	.7530
Beef flavor intensity ^b	10.58	10.80	.25	.5345
Presence of off-flavors ^b	14.77	14.90	.06	.1860
Overall palatability ^b	9.58	9.85	.41	.6368
WB shear force, kg	4.26	4.43	.32	.7053
Cooking loss, %	25.50	25.16	1.23	.8487

^aProbability of observing a greater F-value.

^bEvaluated by trained sensory panel on a 15 cm continuous scale; 15 = juicy, tender, greater intensity, no off-flavors, greater palatability.

TABLE 7. EFFECT OF CALVING UPON SENSORY ATTRIBUTES OF OPEN HEIFERS

Item	Virgin Heifers	First-calf Heifers	SEM	Treatment Effect ^a
No. of animals	12	12		
Juiciness ^b	9.58	9.93	.40	.5402
Tenderness ^b	9.35	8.86	.47	.4618
Beef flavor intensity ^b	10.59	10.80	.25	.5594
Presence of off-flavors ^b	14.81	14.86	.06	.5901
Overall palatability ^b	9.78	9.65	.41	.8246
WB shear force, kg	4.41	4.28	.32	.7769
Cooking loss, %	25.54	25.12	1.23	.8090

^aProbability of observing a greater F-value.

^bEvaluated by trained sensory panel on a 15 cm continuous scale; 15 = juicy, tender, greater intensity, no off-flavors, greater palatability.



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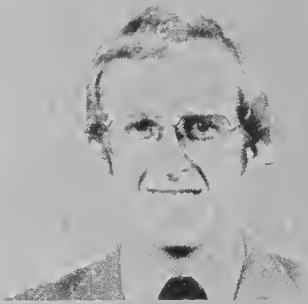
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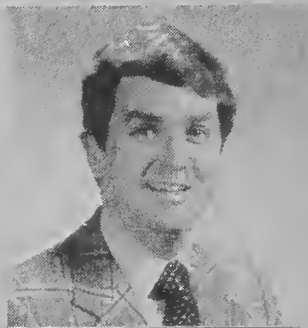
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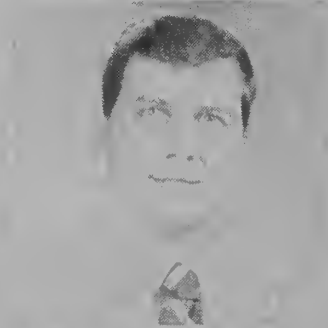
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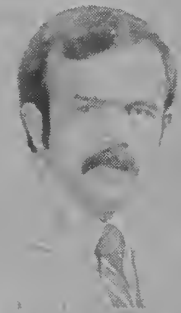
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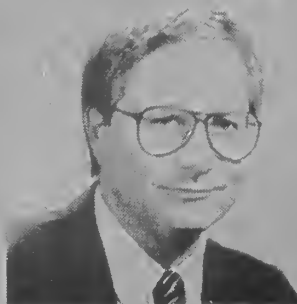
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The Illinois Board of Higher Education recently reaffirmed the Land-Grant mission of the University of Illinois, Urbana-Champaign. The IBHE mission statement reads "The campus' traditional Land-Grant mission focuses on instruction, research and public service in agriculture...". Consistent with that charge the 1994 Beef Cattle Research Report contains the latest research findings from studies conducted at the University of Illinois. We trust that the Report will be of practical benefit to the beef producers of Illinois and the nation. We are delighted to share this information with you.

On November 6, 1993, the newly remodelled and expanded Animal Sciences Laboratory was rededicated. This project was part of the Food for Century III initiative. As a result the students, staff and faculty now have available world-class research and teaching laboratories and classrooms. We appreciate the efforts of all who were involved in securing the funding for Food for Century III.

Please let us know how we can better serve your needs to enhance competitiveness and production efficiency. It is an honor and privilege to work with our beef producers.

EXPLANATION OF STATISTICAL ANALYSIS USED IN THIS BEEF REPORT¹

D. D. Buskirk

Evaluation of treatments and drawing conclusions about a population on the basis of sample data requires statistical analysis. Statistical analysis is necessary because all animals do not perform identically. For example, cattle receiving treatment X may have a greater average daily gain than those receiving treatment Y, however because there is variability within the groups the observed difference between groups may or may not be due to the treatments. Statistical analysis allows researchers to calculate the probability that such differences are from chance rather than the treatment.

In this report you may see the notation ($P < .05$). This means that the probability of the observed difference being due to chance is less than 5%. If two averages (means) are referred to as significantly different ($P < .05$), the probability is less than 5% that these two means are different strictly by chance. In other words, the probability is greater than 95% that the difference was caused by the treatments.

Means may be reported as $2.5 \pm .1$, where 2.5 is the mean and .1 is the standard error (SE). The standard error describes variability in a set of data. There is a 68% probability that the true mean (the mean if we could measure all animals) will be within one SE of the sample mean. There is a 95% probability that the true mean will be within two SE of the sample mean. In this example, there is a 68% probability that the true mean is between 2.4 and 2.6 ($2.5 \pm .1$), and a 95% probability that it is between 2.3 and 2.7.

Correlations may be reported in some articles. A correlation is a measure of the relationship between two traits. The relationship may be positive (both traits get larger or smaller together) or negative (as one trait gets larger the other gets smaller). A perfect correlation is +1 or -1. If there is no relationship the correlation is 0. A high correlation does not necessarily mean that one trait causes the other.

Much of the statistical analysis calculated for this report has been done using the Statistical Analysis System (SAS). SAS is an exceptionally powerful computer program for analyzing experimental data. The research presented in this beef report includes statistical analysis to increase confidence that can be placed in the results.

¹In part from 1993 Kansas Cattlemen's Day Report

INCREASED POSTWEANING GAIN OF LIGHT WEIGHT BEEF HEIFERS ENHANCES FERTILITY AND MILK PRODUCTION

D. D. Buskirk, F. A. Ireland and D. B. Faulkner

SUMMARY

Four hundred fifty-two (452) Angus and Angus-Hereford light weight weanling heifer calves (192 ± 23 kg) (423 lb) were used to determine the effect of postweaning weight gain on subsequent productive performance. During the postweaning treatment period of 136 d (November 5, 1991 to March 20, 1992), heifers grazed stockpiled tall fescue pastures, and were fed a high (H) or low (L) amount of supplement (3.68 and 2.99 kg/(animal·d), {8.1 and 6.6 lb} respectively). Postweaning gain for H and L heifers was .62 and .43 kg/d (1.37 and .95 lb), respectively. Nearly 10% more ($P = .05$) heifers in the H group were pubertal prior to the start of the breeding season (70.7 vs 61.2%). Early puberty did not result in an increase in first service conception rate ($P = .12$) or overall pregnancy rate ($P = .27$) for the H heifers. Mean milk production was 10% greater ($P < .01$) for H compared to L heifers and resulted in calves which weighed more ($P = .04$) at 54, 104, and 153 d of age. Although hip height at weaning was greater ($P = .02$) for calves of H heifers, there was not a significant difference in weaning weight. The probability of heifers reaching puberty prior to the breeding season increased over the range of postweaning gain. Mean milk production also increased over the range of postweaning gain in this study. Increased postweaning gain of light weight beef heifers up to 1.17 kg/d resulted in positive responses in both subsequent fertility and milk production potential.

INTRODUCTION

Nutrition plays a key role in determining the success of replacement heifer development. Several researchers have noted the influence of increased rate of gain on decreased age at puberty and increased calving rates. Overfeeding however, has been shown in some studies to have detrimental effects on conception rates.

Milk production of females is very economically important because of its influence on calf weaning weights. Practices which increase rate of gain prior to puberty, such as creep feeding, have been shown to decrease subsequent milk production.

The rate of postweaning gain resulting in optimum reproductive performance has not been established. In addition, limited information is available on beef heifer milk production differences as a result of postweaning rate of gain. The objectives of this study were to determine the effects of a range of postweaning gain of light weight beef heifers on subsequent fertility and milk production.

MATERIALS AND METHODS

Four hundred fifty-two (452) Angus and Angus-Hereford light weight weanling heifer calves (192 ± 23 kg) were used to determine the effect of postweaning weight gain on subsequent productive performance. The heifers were assigned randomly to two levels of nutrition from weaning to breeding, with two replications per treatment in a completely random design. These spring born calves were purchased from various sources during October 1991 (yr 1) and were placed on tall fescue pastures at the Dixon Springs Agricultural Center, Simpson IL until they were assigned to treatment in November 1991. During the postweaning treatment period of 136 d (November 5, 1991 to March 20, 1992), heifers grazed stockpiled tall fescue pastures, and were fed a high (H) or low (L) amount of supplement (3.68 and 2.99 kg/(animal·d), respectively) (Table 1). These treatments were designed to elicit a range in weight gain.

The beginning and end of the treatment period are referred to as weaning and yearling, respectively. The period from weaning to yearling is referred to as the postweaning period. Beginning and ending weights for the postweaning period were calculated as the mean of full weights taken on two consecutive days. Full weights were also obtained in the fall of 1992 (yr 2) and spring and fall of 1993 (yr 3). Fat thickness between the 12th and 13th ribs was measured using a real-time linear array ultrasound instrument at weaning, yearling and in the fall of yr 2. Hip height was measured at weaning, yearling and in the fall of yr 2 and yr 3. Pelvic area was obtained in the spring and fall of yr 2, and spring of yr 3. Body condition score (BCS; 1 to 9 scale) was assigned in the spring and fall of yr 3.

Concentrations of progesterone were determined in samples of serum collected 10 d before and on the first day of the breeding season in yr 2. Serum was stored at -20°C until assayed for concentrations of progesterone as determined by a validated enzyme immunoassay (Kesler et al., 1990). Heifers were considered pubertal if one or both of the serum samples contained progesterone concentrations ≥ 1.5 ng/ml.

After collection of progesterone data, 33 of the lightest weight heifers were removed from each of the treatment groups. Heifers were then visually sorted into Angus and Angus-Polled Hereford cross phenotypes and artificially inseminated and exposed to Polled Hereford and Angus bulls, respectively. Pregnancy was determined by palpation per rectum 160 d after AI and all non-pregnant heifers were removed from the study. In addition, 18 pregnant heifers that weighed less than 300 kg and had a hip height less than 120 cm were removed.

At parturition, heifers were scored according to degree of calving difficulty (1 = no difficulty, 2 = minor difficulty, 3 = major difficulty, 4 = Caesarean section, 5 = abnormal presentation). Calves were identified and weighed within 24 h after birth and male calves were castrated. Calving date was used to determine calving rate to the first timed AI (283 ± 11 d from AI). Heifers that did not raise a calf or did not raise their own calf were removed from the study. Calves were weaned at 214 ± 18

d of age and had weight and hip height recorded.

Milk production estimates were obtained at 54, 104 and 153 ± 18 d postpartum for heifers by weigh-suckle-weigh procedures. The three milk production estimates were averaged to yield an estimate of average daily milk production. Milk composition was determined at 140 ± 19 d postpartum for a subsample of heifers by milking machine. Solids non-fat (SNF) concentration was determined according to the procedure of Golding (1959). Milk fat and protein concentrations were determined by infrared analysis (Dairy Lab Services, Inc., Dubuque, IA). Intake of SNF, fat and protein were calculated as the component percentage for each treatment \times mean daily milk production. Intake of organic matter was calculated as (SNF intake + fat intake) \times .937. Lactose intake was calculated as organic matter intake - protein intake - fat intake.

Main effects of dietary treatment were analyzed using the GLM procedures of SAS (1985) for a completely random design. Regression techniques were used to evaluate the effects of weaning weight and postweaning gain on subsequent heifer productivity. Heifer fertility was analyzed using logistic regression by the CATMOD procedures of SAS (1985). Maximum R^2 improvement, stepwise regression procedures (SAS, 1985) were used to develop models that describe the effects of postweaning gain and heifer weaning weight on subsequent body measurements. The same stepwise procedures were used to develop models that describe the effects of postweaning gain on subsequent milk production and calf growth. These models included mean calf age at the mean milk production estimate as a covariate.

RESULTS

The L and H groups had a daily consumption of 2.99 and 3.68 kg supplement per animal, respectively (Table 1). Postweaning gain for L and H heifers was .43 and .62 kg/d, respectively (Table 3). Postweaning gain for both groups was lower than expected which may have been due to negative associative effects of these concentrate and forage diets. Heifers receiving H weighed 26 kg more ($P < .0001$) than L at yearling. In the fall of yr 2, H still weighed 19 kg more ($P < .0001$) than L. There was no difference ($P > .46$) in heifer weight due to treatment after the fall of yr 2. Heifers receiving H tended ($P = .08$) to have increased hip height at yearling compared to L, however there was no significant difference after this time. As expected fat thickness was 23 and 26% greater ($P < .0001$) for H heifers at yearling and fall yr 2 measurements. By yr 3 there was no difference ($P > .27$) in BCS between treatment groups. High intake heifers also had 5.3 and 4.9% greater pelvic area as measured in the spring and fall of yr 2. There was a tendency ($P = .12$) for H heifers to have 2.7% larger pelvic area after having their first calf, however calving ease scores did not differ ($P = .33$) for L and H groups (Table 4).

Nearly 10% more heifers in the H group were pubertal prior to the start of the breeding season (61.2 vs 70.7%). Early puberty did not result in an increase in first service conception rate or overall pregnancy rate for the H heifers.

Milk component and milk production estimates are presented in Table 5. Solids nonfat and protein percentages were not significantly different between L and H. Milk fat was .36 percentage units higher for H heifers. The H heifers produced 13% more milk ($P < .01$) at 54 d of lactation and tended ($P = .08$) to produce 17% more milk at 153-d. Mean milk production was 10% greater ($P < .01$) for H compared to L heifers. As would be expected, estimates of milk component intake for calves nursing H dams were all greater ($P < .05$) than for those nursing L dams. Increased milk production from H dams resulted in calves which weighed more ($P = .04$) at 54, 104, and 153 d of age (Table 6). Although hip height at weaning was greater ($P = .02$) for calves of H heifers, there was not a significant difference in weaning weight. Calves of L dams likely increased their forage consumption to compensate for their lower milk intake in late lactation. This idea is supported by the stronger correlation between calf weight and milk consumption at 104-d ($r = .34$) than at 153-d ($r = .10$) (Table 7). In this study, mean milk production of the dam accounted for 49% of the variation in weaning weight of the calf, emphasizing the importance of milk production in beef cows. Milk component intake did not aid in explaining variation in calf weaning weight beyond that of mean milk production.

Regression equations are given in Table 8 that describe heifer growth characteristics as influenced by weaning weight and postweaning weight gain. Figure 1 shows graphically those heifer growth characteristics that were measured in the fall of yr 2 (equations from Table 8). From this set of figures it can be seen that as weaning weight and postweaning gain increased, weight, hip height, fat thickness and pelvic area in the fall of yr 2 all increased.

Probability of reaching puberty prior to breeding as influenced by weaning weight and postweaning gain is shown in Figure 2. As weaning weight and postweaning gain increased, so did the probability for reaching puberty before the breeding season. Figure 3 demonstrates the importance of weaning weight on the probability of conceiving to the first AI. Increasing weaning weight from 150 to 275 kg increased the probability of conceiving to the first AI from 5.8 to 45.5%.

Regression equations are given in Table 9 for calf growth characteristics and milk production of their dams. Mean milk production as influenced by weaning weight and postweaning weight gain is shown in Figure 4 (equation from Table 9). This graph reveals that increasing weaning weight and postweaning gain increased subsequent milk production over the ranges in this study.

CONCLUSIONS

Increasing postweaning gain of light weight Angus and Angus-Hereford heifers from .07 to 1.17 kg/d (.2 to 2.6 lb/d) increased the number of pubertal heifers prior to the breeding season. In addition, increasing rate of postweaning gain increased milk production over this same range of weight gain. This study demonstrates that heifers of this type may have postweaning weight gain up to 1.17 kg/d (2.6 lb/d) without detrimental effects on subsequent productive performance.

LITERATURE CITED

Golding, N. S. 1959. A solids non-fat test for milk using density plastic beads as hydrometers. J. Dairy Sci. 42:899 (Abstr.).

Kesler, D. J., H. Khazali and R. J. Favero. 1990. Quantification of steroids via a polymer linked second antibody enzyme immunoassay system: Methods of linking anti-rabbit IgG to polystyrene. In: Progress in Biomedical Polymers. Ed., C. G. Gebelein and R. L. Dunn, Plenum Publishing Co., New York, NY, p. 157-170.

SAS. 1985. SAS User's Guide. SAS Inst., Inc., Cary, NC.

TABLE 1. SUPPLEMENT COMPOSITION AND INTAKE ON DM BASIS

Item	Low intake	High intake
Ground corn, %	96	98
Urea, %	4	2
Vitamin A, IU/kg supplement	11023	11023
Rumensin, mg/(animal·d)	150	150
Supplement intake, kg/(animal·d)	2.99	3.68

TABLE 2. MEANS, STANDARD DEVIATIONS, MINIMUM AND MAXIMUM VALUES OF MEASUREMENTS

Variable	n	Mean	SD	Minimum	Maximum
Postweaning gain, kg/d	448	.52	.18	.07	1.17
<u>Weight, kg</u>					
Weaning	452	192	22.5	142	274
Yearling	448	263	34.7	176	386
Fall yr 2	376	293	33.8	210	373
Spring yr 3	211	347	34.9	269	447
Fall yr 3	205	330	35.3	239	429
<u>Hip height, cm</u>					
Weaning	452	104	3.4	97	116
Yearling	448	108	4.5	86	122
Fall yr 2	374	117	3.9	104	130
Fall yr 3	205	121	4.6	107	133
<u>Fat thickness, cm</u>					
Weaning	452	.51	.06	.30	.70
Yearling	447	.71	.18	.00	1.4
Fall yr 2	376	.38	.15	.00	.80
<u>BCS</u>					
Spring yr 3	212	3.6	.7	2	5
Fall yr 3	205	3.4	.6	2	5
<u>Pelvic area, cm²</u>					
Spring yr 2	373	160.7	18.2	114.0	217.5
Fall yr 2	376	185.6	26.9	104.5	252.0
Spring yr 3	206	260.5	32.2	135.0	332.5
Calving ease score	243	1.5	.9	1	5
<u>Calf</u>					
Birth weight, kg	244	29.4	4.6	13.6	41.7
54-d weight, kg	209	52.3	12.5	22.9	87.8
104-d weight, kg	204	78.8	16.4	36.3	128.7
153-d weight, kg	202	107.5	20.1	56.5	160.0
214-d weight, kg	201	139.9	23.3	81.6	197.8
214-d hip height, cm	201	96.4	5.5	81.3	110.5
Age at weaning, d	201	214	18.2	174	250

TABLE 3. HEIFER GROWTH AS INFLUENCED BY LEVEL OF NUTRITION POSTWEANING

Item	n	Treatment		P
		Low intake	High intake	
Postweaning gain, kg/d	448	.43 ± .01	.62 ± .01	.0001
<u>Weight, kg</u>				
Weaning	452	192.6 ± 1.5	191.8 ± 1.5	.69
Yearling	448	250.3 ± 2.2	275.9 ± 2.1	.0001
Fall yr 2	376	283.9 ± 2.4	302.8 ± 2.4	.0001
Spring yr 3	211	347.6 ± 3.5	346.8 ± 3.3	.87
Fall yr 3	205	327.7 ± 3.6	331.3 ± 3.4	.46
<u>Hip height, cm</u>				
Weaning	452	104.1 ± .2	103.9 ± .2	.40
Yearling	448	107.8 ± .3	108.5 ± .3	.08
Fall yr 2	374	117.2 ± .3	117.8 ± .3	.14
Fall yr 3	205	121.3 ± .5	120.9 ± .4	.54
<u>Fat thickness, cm</u>				
Weaning	452	.51 ± .004	.51 ± .004	.38
Yearling	447	.64 ± .01	.79 ± .01	.0001
Fall yr 2	376	.34 ± .01	.43 ± .01	.0001
<u>BCS</u>				
Spring yr 3	212	3.6 ± .07	3.5 ± .06	.27
Fall yr 3	205	3.4 ± .07	3.3 ± .06	.45
<u>Pelvic area, cm²</u>				
Spring yr 2	373	156.5 ± 1.3	164.8 ± 1.3	.0001
Fall yr 2	376	181.2 ± 1.9	190.0 ± 1.9	.001
Spring yr 3	206	256.6 ± 3.3	263.5 ± 3.1	.12

TABLE 4. HEIFER FERTILITY AS INFLUENCED BY LEVEL OF NUTRITION POSTWEANING

Item	n	Treatment		P
		Low intake	High intake	
Pubertal prior to breeding, %	380	61.2 ± 3.4	70.7 ± 3.4	.05
First service conception, %	359	21.9 ± 3.5	15.1 ± 3.3	.12
Pregnancy yr 2, %	377	71.1 ± 4.4	65.1 ± 4.1	.27
Calving ease score	238	1.4 ± .07	1.5 ± .07	.33
Pregnancy yr 3, %	205	79.6 ± 3.8	86.6 ± 3.6	.19

TABLE 5. ESTIMATED MILK AND MILK COMPONENT PRODUCTION OF HEIFERS AS INFLUENCED BY LEVEL OF NUTRITION POSTWEANING

Item	n	Treatment		P
		Low intake	High intake	
<u>Milk component, %</u>				
Solids nonfat	19	7.94 ± .08	8.06 ± .07	.26
Fat	20	4.02 ± .12	4.38 ± .03	.03
Protein	20	3.06 ± .10	3.01 ± .10	.71
<u>Milk production estimate, kg/d</u>				
54-d	209	3.8 ± .1	4.3 ± .1	.008
104-d	204	3.1 ± .1	3.3 ± .1	.15
153-d	202	1.8 ± .1	2.1 ± .1	.08
Mean	209	2.9 ± .1	3.2 ± .1	.007
<u>Milk component intake estimate, kg/d</u>				
Organic matter	209	.32 ± .01	.38 ± .01	.0003
Solids nonfat	209	.23 ± .007	.26 ± .007	.002
Fat	209	.12 ± .004	.14 ± .004	.0001
Protein	209	.09 ± .003	.10 ± .003	.02
Lactose	209	.12 ± .004	.14 ± .004	.0004

TABLE 6. CALF GROWTH AS INFLUENCED BY THEIR DAMS LEVEL OF NUTRITION POSTWEANING

Item	n	Treatment		<i>P</i>
		Low intake	High intake	
Birth weight, kg	244	29.0 ± .42	30.0 ± .41	.17
<u>Calf shrunk weight, kg</u>				
54-d	212	51.0 ± .9	53.6 ± .9	.04
104-d	207	76.8 ± 1.4	80.8 ± 1.3	.04
153-d	205	104.9 ± 1.8	110.0 ± 1.7	.04
214-d	204	138.0 ± 2.3	142.1 ± 2.1	.20
Weaning hip height, cm	204	95.4 ± .5	97.2 ± .5	.02

TABLE 7. CORRELATIONS AMONG CALF WEIGHT AND ESTIMATED MILK FLUID AND COMPONENT CONSUMPTION (r)*

	Milk fluid intake, kg/d			Milk component intake, kg/d					
	54-d	104-d	153-d	Mean	OM	SNF	Fat	Protein	Lactose
Calf weight, kg									
54-d	.22	.22	-.03	.18	.18	.18	.18	.18	.18
104-d	.30	.34	.05	.30	.30	.30	.30	.30	.30
153-d	.36	.40	.10	.38	.38	.38	.38	.38	.38
214-d	.42	.49	.21	.49	.48	.49	.48	.49	.48

*Null hypothesis is $|R| = 0$; Correlation whose absolute value is $> .16$ is significantly different from zero ($P < .01$)

TABLE 8. REGRESSION OF GROWTH CHARACTERISTICS ON WEANING WEIGHT AND POSTWEANING GAIN

Variable	n	Intercept	Initial wt, kg	Regression coefficient estimates				Initial wt, kg Postweaning gain, kg/d	R ²	
				Postweaning gain, kg/d	Postweaning gain, kg/d ²	Postweaning gain, kg/d ³				
<u>Weight, kg</u>										
Fall yr 2	376	84.73	.79 ± .07	96.32 ± 7.88					.43	
Spring yr 3	211	82.75	1.19 ± .44	299.83 ± 149.41				-1.26 ± .74	.11	
Fall yr 3	205	196.15	.55 ± .11		69.40 ± 11.35					
<u>Hip height, cm</u>										
Yearling	448	77.57	.13 ± .02	27.59 ± 8.67				-.09 ± .04	.37	
Fall yr 2	374	103.17	.05 ± .009	7.49 ± 1.11					.16	
Fall yr 3	205	111.35	.04 ± .02			7.44 ± 1.65			.11	
<u>Fat thickness, cm</u>										
Yearling	447	.47		-.50 ± .12				.0049 ± .0005	.37	
Fall yr 2	376	.22						.0015 ± .0002	.13	
<u>BCS</u>										
Spring yr 3	212	-.84	.021 ± .009	6.05 ± 3.01				-.03 ± .01	.04	
<u>Pelvic area, cm²</u>										
Spring yr 2	373	92.73	.29 ± .04		32.80 ± 4.02				.24	
Fall yr 2	376	100.11	.36 ± .06		43.97 ± 6.17				.18	
Spring yr 3	206	238.11						.20 ± .07	.04	

TABLE 9. REGRESSION OF CALF WEIGHT, HIP HEIGHT AND DAM MILK PRODUCTION ON WEANING WEIGHT AND POSTWEANING GAIN OF THEIR DAM

Variable	n	Intercept	Calf age, d	Regression coefficient estimates			R ²
				Postweaning gain, kg/d	Postweaning gain, kg/d ³	Initial wt, kg x Postweaning gain, kg/d	
<u>Calf shrunk weight, kg</u>							
54-d	209	-2.14	.46	-21.75		.18	.51
104-d	204	12.33	.53			.11	.39
153-d	202	37.93	.53			.13	.28
214-d	201	86.39	.36			.14	.13
<u>Calf hip height, cm</u>							
214-d	201	84.23	.073			.041	.13
<u>Milk production estimate, kg/d</u>							
54-d	209	4.92	-.021			.01	.16
104-d	204	3.31	-.011			.0091	.09
153-d	202	3.80	-.021		1.11		.12
Mean	209	3.85	-.017			.0090	.19

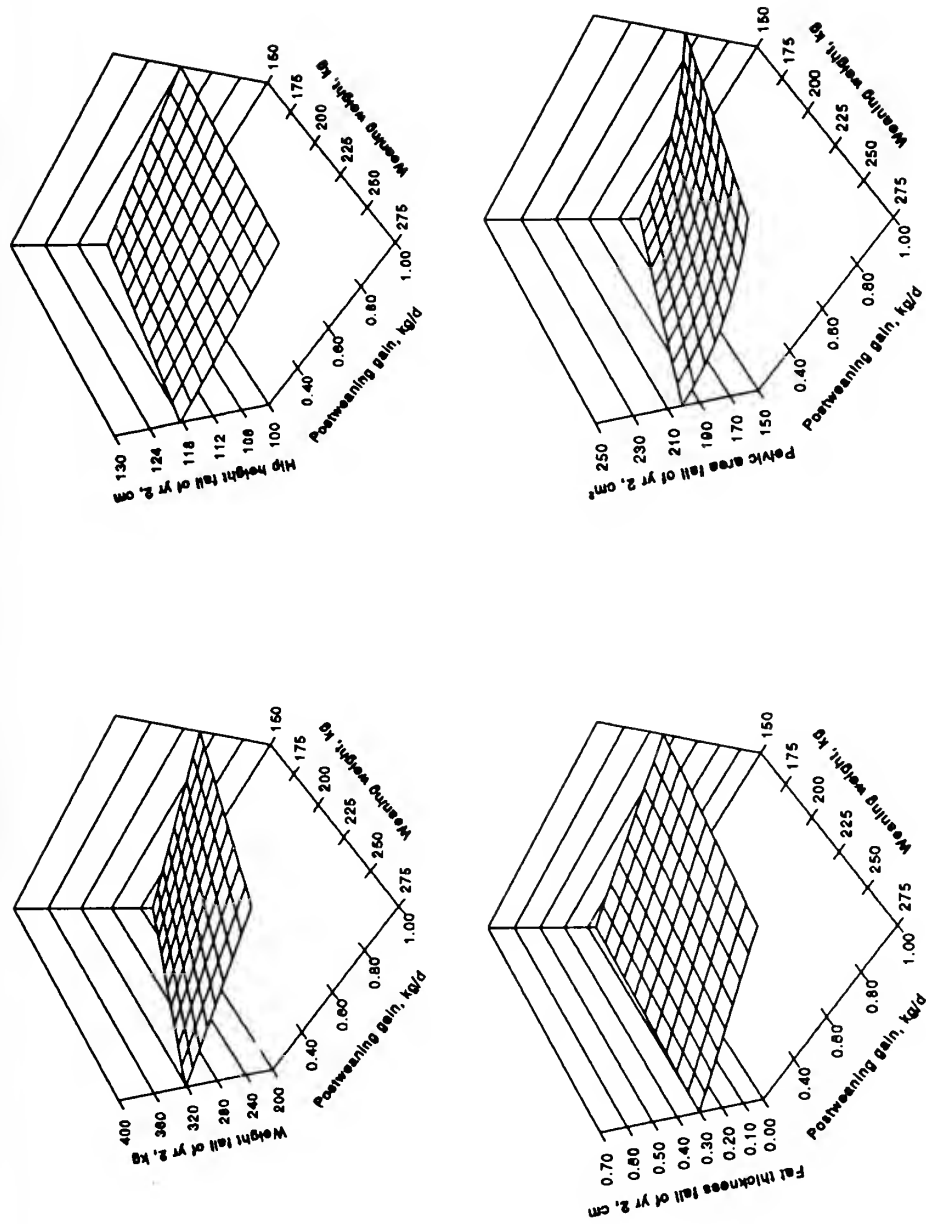


Figure 1. Response surface of heifer growth characteristics measured fall of year 2 on weaning weight and postweaning gain

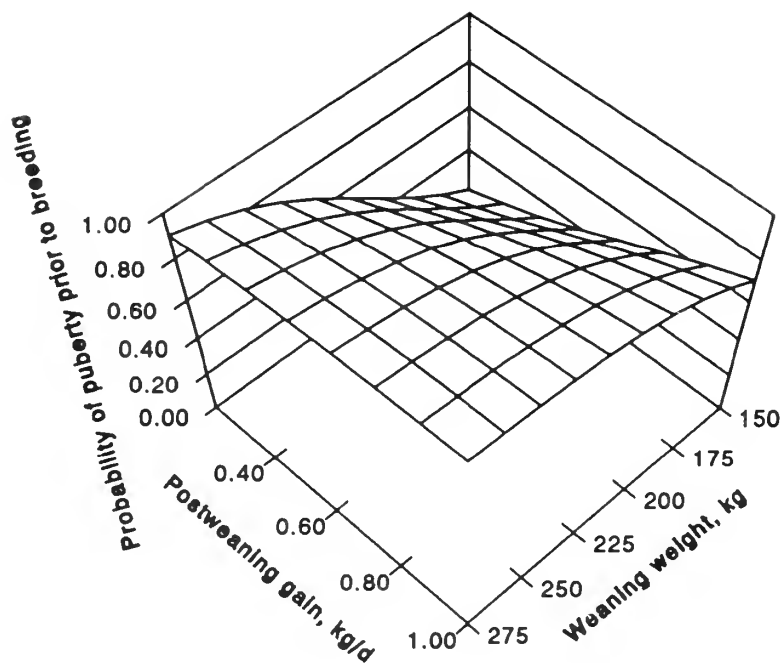


Figure 2. Logistic regression of probability of reaching puberty prior to the start of breeding on weaning weight and postweaning gain

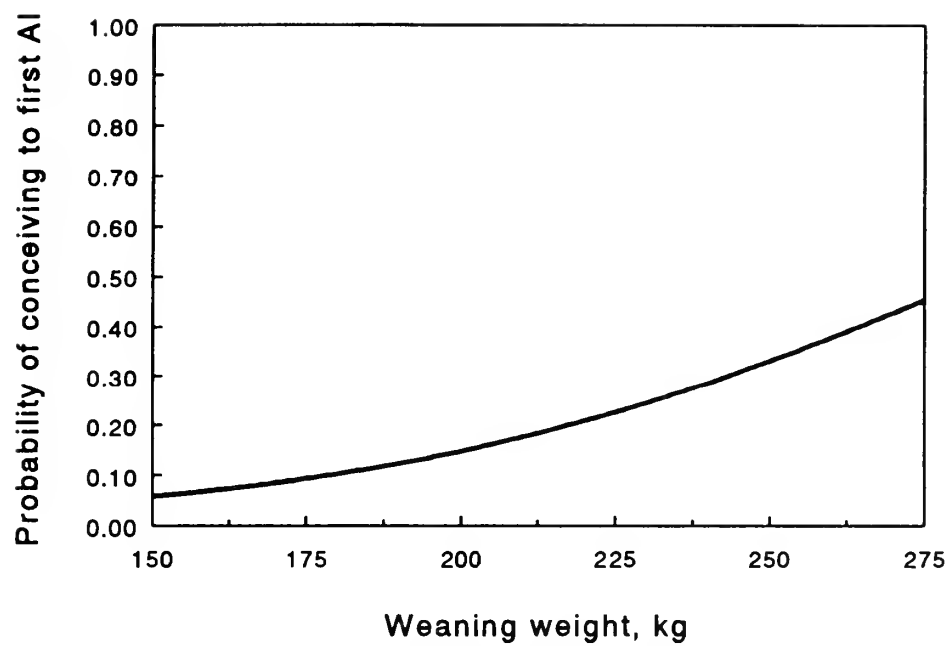


Figure 3. Logistic regression of probability of calving to the first AI service on weaning weight

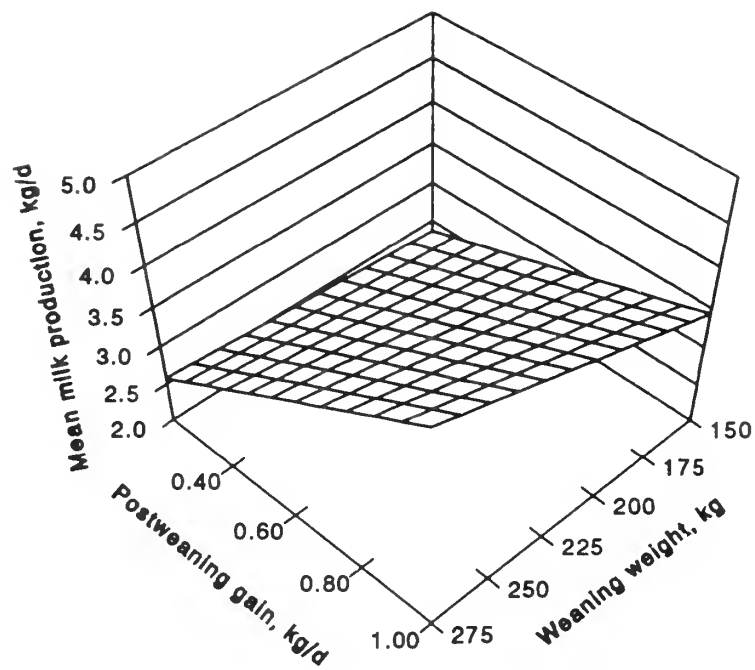


Figure 4. Response surface of mean milk production on weaning weight and postweaning gain

LIMIT FEEDING WHOLE OR CRACKED CORN-HAY DIETS COMPARED TO AN AD LIBITUM HAY DIET FOR BEEF COWS

D. B. Faulkner, J. W. Castree and D. D. Buskirk

SUMMARY

Sixty-three Angus x Simmental crossbred cows (1281 ± 27 lb) with Simmental sired calves (85.6 ± 2.7 lb) were utilized in three replicates to evaluate three treatments. The three treatments were ad libitum hay, limited cracked corn (13.6 lb) and hay (10.4 lb), and limited whole corn (13.6 lb) and hay (10.4 lb). The cows and calves were on study starting 24 hours after parturition until the beginning of breeding (average of 64 days). Cows on the whole corn diet tended ($P = .08$) to lose more weight than the cows on the cracked corn diet and the limit fed cows lost more weight ($P < .05$) than the ad libitum fed hay cows. Subsequent conception rate was not influenced ($P > .23$) by treatment. The results suggest that all the treatments resulted in cow performance that was adequate for good reproductive success. Intake was reduced ($P < .001$) for the limit fed treatments as expected. This intake reduction for the mixed diet lowered the daily feed cost over a wide range of prices of corn and hay. The only exception was when hay was very low cost (less than \$60/ton) and corn was high priced (more than \$3.00/bu). Calf gain tended ($P = .12$) to be reduced by limit feeding, but no difference was observed ($P > .74$) in weaning weight. Cows in early lactation can be limit fed a corn-hay diet resulting in adequate performance and lowered feed costs.

INTRODUCTION

Feed costs account for over 50% of the total costs in cow-calf production systems. One method of reducing feed costs is to limit feed grain. Roughage must be fed with grains to ensure proper rumen function (usually at least .5% of body weight). Limit feeding is cost effective when grains or coproducts are a cheaper source of energy than hay. Corn is often an inexpensive readily available high energy feedstuff for midwest beef producers. However, many producers lack corn processing equipment. Therefore, it is important to establish if the corn needs to be processed when it is limit fed to beef cows. The objectives of this study were to evaluate a limit fed corn-hay diet compared to an ad libitum hay diet and to evaluate the necessity of processing corn for the limit fed cow diet.

PROCEDURE

Sixty-three Angus x Simmental crossbred cows (1281 ± 27 lb) with Simmental sired calves (85.6 ± 2.7 lb) were utilized in three replicates to evaluate three treatments. This resulted in nine pens with 7 cow-calf pairs per pen. The three treatments were ad libitum hay, limited cracked corn (13.6 lb) and hay (10.4 lb), and limited whole corn (13.6 lb) and hay (10.4 lb). The diets were formulated to supply similar amounts of energy based on a predicted intake of 35 lb on the hay diet and to

ensure that all other nutrients met or exceeded National Research Council recommendations. The cows and calves were placed on the study starting 24 hours after parturition and remained on study until the beginning of breeding (average of 64 days). Cows were randomly assigned to treatment and blocked by calving date. Initial cow weights were taken within 24 hours of calving prior to feeding. Calf birth weights were used as initial weights. Final weights were taken after they had been fed a common diet for three days and removed from feed and water for 16 hours to reduce fill differences. Hay fed and refused was weighed and sampled for dry matter determination. Cow gain, cow condition change, calf gain, subsequent cow conception rate, and subsequent cow and calf performance were evaluated. Three cow-calf pairs were removed from the study for reasons unrelated to treatment.

Data were analyzed using SAS with pen as the experimental unit. Orthogonal contrasts were hay vs limited corn-hay treatments and whole vs cracked corn.

RESULTS

Cows on the whole corn diet tended ($P = .08$) to lose more weight than the cows on the cracked corn diet and the limit fed cows lost more weight ($P < .05$) than those fed the hay diet. However, no difference ($P = .74$) in cow condition score change was observed. Part of the improved performance on the hay diet was a result of higher consumption than was predicted (36.1 vs 35 lb). This resulted in slightly higher energy intake for the hay diet than the limit fed corn-hay diets.

Subsequent cow gain from the end of the study to weaning tended ($P = .08$) to be influenced by previous treatment; however, a contrasting influence tended ($P = .16$) to be observed in condition score change. These results are inconsistent and are probably due to random chance. Cow conception was not influenced ($P > .23$) by previous treatment. These results suggest that all the treatments resulted in cow performance that was adequate for good reproductive success. Processing the corn may improve cow performance, but the processing costs should be considered.

Intake was reduced ($P < .001$) for the limit fed treatments as expected. This intake reduction for the mixed diet lowered the daily feed cost over a wide range of prices of corn and hay (Table 2). The only exception was when hay was very low cost (less than \$60/ton) and corn was high priced (more than \$3.00/bu). This cost includes feed ingredient costs only. It does not include processing or feeding costs, shrink or feed spoilage.

Calf gain tended ($P = .12$) to be reduced by limit feeding (Table 1), but this difference was not still observed ($P > .74$) at weaning. Therefore, the cow nutrition treatments had little influence on overall calf performance.

CONCLUSIONS

Cows in early lactation can be limit fed on a corn-hay diet. Cow performance can be improved by processing the corn, but the processing costs must be considered. Calf performance at weaning was not influenced by cow nutrition during early lactation. Costs can be reduced substantially with the limit feeding program. Using the actual costs for these feedstuffs in late 1992, the savings were about \$.54/day/cow.

TABLE 1. LIMIT FEEDING HAY AND WHOLE OR CRACKED CORN COMPARED TO AD LIBITUM HAY FOR BEEF COWS

	Hay	Limit whole corn and hay	Limit cracked corn and hay	SE
Initial cow wt., lb	1289	1285	1269	27
Cow gain ^{ab} , lb/d	- .09	- .99	- .39	.18
Initial condition score	6.5	6.5	6.5	.14
Condition score change	- .90	- .83	- .90	.15
Initial calf wt., lb	87.7	82.4	86.7	2.7
Calf gain, lb/d	2.69	2.48	2.55	.07
Intake ^{cd} , lb	36.1	24.0	24.0	.63
Subsequent performance through weaning ^e				
Calf weaning wt., lb	505	485	481	20
Calf gain, lb/d	1.82	1.89	1.93	.19
Cow weight at weaning, lb	1185	1170	1150	21
Cow gain ^b , lb/d	- .77	- .40	- .74	.10
Cow condition change	- .20	- .60	- .36	.14
Cow conception, %	95.3	100	100	.03

^aHay vs limited corn (P<.05)

^bWhole vs cracked corn (P = .08)

^cHay vs limited corn (P<.001)

^dThe limit fed treatments were fed 10.4 lb of hay and 13.6 lb of corn.

^ePerformance for the 134 days following the study, until weaning at an average calf age of 198 days.

TABLE 2. SAVINGS (\$/COW/DAY) FOR A LIMIT FED CORN-HAY DIET AT VARYING PRICES OF CORN AND HAY COMPARED TO AN AD LIBITUM HAY DIET

Hay cost		Corn Price, \$/bu							
\$/T	\$/d	1.80	2.00	2.20	2.40	2.60	2.80	3.00	3.20
50	1.06	.24	.18	.13	.07	.01	-.04	-.10	-.16
55	1.17	.32	.26	.20	.15	.09	.03	-.03	-.08
60	1.27	.39	.34	.28	.22	.16	.11	.05	-.01
65	1.38	.47	.41	.35	.30	.24	.18	.13	.07
70	1.49	.54	.49	.43	.37	.32	.26	.20	.14
75	1.59	.62	.56	.51	.45	.39	.33	.28	.22
80	1.70	.70	.64	.58	.52	.47	.41	.35	.30
85	1.81	.77	.71	.66	.60	.54	.49	.43	.37
90	1.91	.85	.79	.73	.67	.62	.56	.50	.45
95	2.02	.92	.86	.81	.75	.69	.64	.58	.52
100	1.12	1.00	.94	.88	.83	.77	.71	.65	.60
105	2.23	1.07	1.02	.96	.90	.84	.79	.73	.67
110	2.34	1.15	1.09	1.03	.98	.92	.86	.81	.75

EFFECTS OF ZINC AND COPPER PROTEINATE SUPPLEMENTATION ON PERFORMANCE, CARCASS TRAITS, AND HOOF DURABILITY IN FEEDLOT HEIFERS

B. A. Reiling, L. L. Berger, G. L. Riskowski, and T. G. Nash

SUMMARY

One hundred ninety-two yearling heifers were fed 180 mg per head per day of supplemental Zn from ZnSO_4 or Zn proteinate alone and in combination with 50 mg supplemental Cu from CuSO_4 or Cu proteinate for 123 d to evaluate the effects of Zn and Cu type upon growth performance, carcass characteristics, and hoof strength. Heifers were allotted at random to one of four treatments which were replicated three times resulting in a total of 12 pens with 16 head per pen. The cattle were housed in complete confinement on concrete slats. Performance data analyzed included dry matter intake, average daily gains, and gain/feed ratios. Carcass data was collected 24 h post-mortem and included yield and quality traits. Statistical differences among the 4 treatments were minimal for most performance and carcass traits evaluated. Cu and Zn in combination did appear to decrease the incidence of dark cutters. Upon slaughter, front hooves from each animal were also collected. The bottom of each toe was planed, and a cross-sectional 5 mm thick slice obtained for shear analysis. An MTS material testing machine was utilized to measure the force required to shear a 1.3 cm diameter hole through the bottom side of the hoof slice. The completely randomized design was analyzed with the GLM procedure of SAS and hoof thickness was used as a covariate in all statistics regarding hoof strength. No differences due to type of zinc supplementation existed for maximum force required for shearing. However, the inclusion of Cu appeared to decrease the overall strength of hooves. The addition of supplemental CuSO_4 to the diet of ZnSO_4 treated hooves reduced maximal shearing force by 5.7% and the addition of supplemental Cu proteinate to Zn proteinate treated hooves reduced shearing force by 2.6%. Slopes of elastic and permanent deformation were not significantly different among treatments.

INTRODUCTION

In recent years, the use of trace minerals complexed to organic compounds has received much publicity. It has been postulated that these complexes may exhibit enhanced absorption and utilization as compared to the inorganic trace minerals.

Of particular interest to beef and dairy producers, is how Zn proteinate complexes may improve the immune response and enhance the keratinization of epithelial tissues resulting in a potential decline in the incidence of foot rot problems.

Thus, the objective of this trial was to compare the effectiveness of supplemental ZnSO_4 and Zn proteinate alone and in combination with CuSO_4 and Cu proteinate upon growth, carcass merit, and overall hoof strength.

MATERIALS AND METHODS

Following a 12 h fast, 192 yearling heifers were weighed and randomly assigned to one of four treatment groups. These treatments included supplementation of all heifers with 180 mg Zn per head per day as either ZnSO₄ or Zn proteinate. Additionally, half the heifers also received 50 mg supplemental Cu per head per day as either CuSO₄ or Cu proteinate. These treatments were replicated three times resulting in a total of 12 pens with 16 head per pen. The pens were contained within a 3-sided confinement structure and utilized concrete slatted floors.

Heifers were fed a 12.25% crude protein diet consisting of 52% corn, 25% corn gluten feed, 5% corn distillers solubles, 5% corn silage, and 8% supplement on a dry matter basis. The supplement composition is shown in Table 1. Overall, the diet was formulated to meet or exceed the NRC (1984) requirements for CP, Ca, P, K, trace minerals, and vitamins prior to the addition of supplemental Zn and Cu.

Throughout the feeding trial, interim weights were taken every 28 d. After 123 d, a final 12 h shrunk weight was taken and used for the termination of performance data. Performance data evaluated included daily dry matter intake, average daily gain, and efficiency of gain expressed as a gain to feed ratio.

Upon termination of the production phase of the study, cattle were transported approximately 320 km (200 mi) to a commercial packing plant where hoof samples and carcass data were collected. Twenty-four h post-mortem, carcass yield and quality traits were evaluated by trained University of Illinois personnel. Yield factors included fat thickness at the 12th rib, longissimus muscle area, hot carcass weight, and percent kidney, pelvic, and heart fat. From these factors a final yield grade was calculated. Quality traits included marbling score and the percentage of dark cutters present.

Upon slaughter, a front hoof from each animal was collected and stored at 0° C until subsequent analyses were performed. The bottom of each toe (two toes per hoof) was planed, and a cross-sectional 5 mm (.2 in) thick slice obtained for shear analysis. An MTS material testing machine was outfitted with a shear apparatus to measure the force required to shear a 1.3 cm (.5 in) diameter hole through the bottom side of the hoof. Prior to shearing, hooves were measured with a micrometer to obtain actual thickness which was used as a covariate for all statistical analyses.

Data collected from the hoof slices included maximum force required for penetration, slope of elastic deformation, and slope of permanent deformation (Figure 1). The slope of elastic deformation, for which no physical damage has yet occurred, was determined as the force required per mm thickness through 2 mm of compression. The slope of permanent deformation was determined as the force required per mm thickness for actual shearing of the sample.

A protected F-test as determined by the GLM procedure of SAS (1988) was used to assess differences in treatment means of the completely randomized design. In addition, meaningful contrasts of Cu vs no Cu and sulfate vs proteinate supplement types were analyzed.

RESULTS AND DISCUSSION

Table 2 shows the effect of Zn and Cu supplementation upon indices of hoof strength. Maximum force required for shearing and kg force per mm of total thickness revealed no differences due to type of zinc supplementation. However, the addition of a copper component fed at 50 mg per head per day appeared to decrease the overall strength of the hooves. Additionally, the greatest reduction in maximal force required occurred when CuSO_4 was added as compared to Cu proteinate. The addition of supplemental CuSO_4 to the diet of the ZnSO_4 treated heifers reduced maximal shearing force by 5.7%. The addition of supplemental Cu proteinate, however, only reduced the maximal shearing force of Zn proteinate treated hooves by 2.6%. It appears the Cu has potentially interacted and perhaps decreased overall Zn absorption, reducing the positive effects that Zn supplementation may have on improving hoof durability (Reiling et al., 1992). The contrast of Cu vs no Cu was significant for maximum force ($P < .10$) and force required per mm of total thickness ($P < .05$). It would also appear the CuSO_4 interacts more strongly and negatively with ZnSO_4 than does the Cu proteinate with Zn proteinate. No statistical differences were observed among the four treatments for the slope of elastic or permanent deformation.

The carcass characteristics of heifers are shown in Table 3. Among the four treatments, few differences can be observed. The addition of Cu as either a CuSO_4 or Cu proteinate form did tend to reduce the percentage of dark cutters. Perhaps the Cu serves to reduce the metabolic effects associated with stress and the increased incidence of "dark cutters" among stressed cattle.

Growth performance characteristics of the cattle are shown in Table 4. Overall, heifers consumed approximately 8.8 kg dry matter per day, gained 1.42 kg/d, and had a gain to feed ratio or efficiency of .161. No differences were observed among the treatments.

IMPLICATIONS

Unlike the findings shown in our preliminary report (Reiling et al., 1992), Zn proteinate did not appear to enhance hoof strength and integrity. However, it was shown that additional Cu supplementation may interact with the Zn and decrease hoof strength. This negative interaction also appears to be greatest when cattle are fed the inorganic mineral forms as compared to the proteinates. The additional Cu and Zn supplementation had little effect upon the performance and carcass traits of these heifers.

LITERATURE CITED

NRC. 1984. Nutrient Requirements of Beef Cattle (6th Ed.). National Academy Press, Washington, DC.

SAS. 1988. SAS User's Guide: Statistics. SAS Inst., Inc., Cary, NC.

Reiling, B. A., L. L. Berger, G. L. Riskowski, and R. E. Rompala. 1992. Effects of zinc proteinate on hoof durability in feedlot heifers. J. Anim. Sci. 70(Suppl. 1): 313 (Abstr.).

FIGURE 1. DIAGRAM OF FORCE REQUIRED TO SHEAR A 5 mm THICK HOOF SLICE

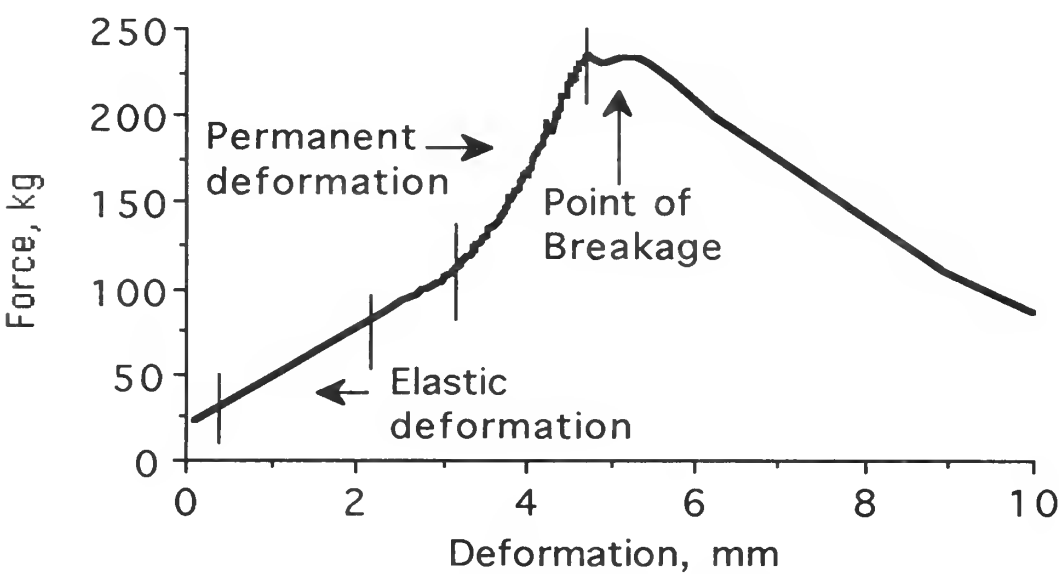


TABLE 1. COMPOSITION OF SUPPLEMENT (DM BASIS)

Ingredients	% (dm basis)
Ground corn	63.33
Soybean meal	5.00
Urea	8.70
Limestone	14.90
Potassium chloride	3.80
Rumensin 60 ^a	.26
Tylan 40 ^b	.16
Trace mineralized salt with Selenium	3.75
Vitamin A, D, E premix	.10

^aSupplies 312 g Rumensin per ton of supplement.

^bSupplies 125 g Tylan per ton of supplement.

TABLE 2. EFFECT OF ZINC AND COPPER SUPPLEMENTATION UPON HOOF STRENGTH

Item	ZnSO ₄	Zn Prot	ZnSO ₄	Zn Prot	SEM
			CuSO ₄	Cu Prot	
Maximum force, kg ^y	224.6 ^a	222.5 ^a	211.7 ^b	216.8 ^{ab}	5.0
kg force/mm thickness ^z	44.28 ^a	43.85 ^a	41.59 ^b	42.58 ^{ab}	.98
Slope of elastic deformation					
kg force/mm thickness	21.84	22.66	21.75	21.84	.57
Slope of permanent deformation					
kg force/mm thickness	46.25	45.69	46.07	42.27	1.96

^{ab}Means with different superscripts differ ($P < .12$).

^yThe contrast of Cu vs No Cu is significant ($P < .10$).

^zThe contrast of Cu vs No Cu is highly significant ($P < .05$).

TABLE 3. EFFECT OF ZINC AND COPPER SUPPLEMENTATION UPON CARCASS CHARACTERISTICS

Item	ZnSO ₄	Zn Prot	ZnSO ₄	Zn Prot	SEM
			CuSO ₄	Cu Prot	
Hot carcass weight, kg	309.2	305.2	310.8	311.1	3.1
Ribeye area, cm ²	83.51	83.78	84.47	81.65	1.11
Fat thickness, cm	1.08	1.06	1.07	1.13	.07
KPH, % 2.62	2.66	2.57	2.53	.07	
Yield Grade 2.54	2.47	2.48	2.68	.10	
Marbling Score ^{y,z}	1019. ^{ab}	1027. ^a	1000. ^b	1015. ^{ab}	9
% dark cutters ^z	28.2 ^a	24.1 ^a	8.4 ^b	12.8 ^{ab}	5.6

^{ab}Means with different superscripts differ ($P < .05$).

^yMarbling Scores: 900 = slight⁰, 1000 = small⁰, 1100 = modest⁰.

^zThe contrast of Cu vs No Cu is significant ($P < .10$).

TABLE 4. EFFECT OF ZINC AND COPPER SUPPLEMENTATION UPON GROWTH PERFORMANCE CHARACTERISTICS

Item	ZnSO ₄	Zn Prot	ZnSO ₄ CuSO ₄	Zn Prot Cu Prot	SEM
Overall DMI, kg/d	8.88	8.68	8.82	8.85	.11
Overall ADG, kg/d	1.43	1.42	1.40	1.42	.04
Overall G/F ratio	.161	.163	.158	.160	.003
Period 1 DMI, kg/d	7.99	7.98	8.19	8.12	.09
Period 1 ADG, kg/d	2.13	2.14	2.24	2.26	.07
Period 1 G/F ratio	.267	.268	.273	.278	.008
Period 2 DMI, kg/d	9.16	8.85	9.10	9.23	.16
Period 2 ADG, kg/d	1.49	1.55	1.42	1.39	.13
Period 2 G/F ratio	.267	.268	.273	.278	.008
Period 3 DMI, kg/d	9.54	9.41	9.45	9.50	.16
Period 3 ADG, kg/d	1.42	1.25	1.33	1.28	.05
Period 3 G/F ratio	.149	.133	.140	.135	.005
Period 4 DMI, kg/d	9.33	9.02	9.10	9.14	.15
Period 4 ADG, kg/d	1.03	.98	1.06	1.11	.05
Period 4 G/F ratio ^z	.111	.109	.116	.122	.004
Period 5 DMI, kg/d	7.68	7.43	7.42	7.44	.14
Period 5 ADG, kg/d	.57	.77	.25	.48	.19
Period 5 G/F ratio	.073	.103	.035	.065	.025

^zThe contrast of Cu vs No Cu is significant ($P < .10$)

EVALUATION OF A NONPROTEIN NITROGEN BYPRODUCT AS AN INGREDIENT IN DIETS FOR GROWING BEEF CATTLE

H. S. Hussein, N. R. Merchen, L. L. Berger and T. G. Nash

INTRODUCTION

Proteoferm is a byproduct of the fermentative production of glutamic acid (monosodium glutamate). It contains about 40% crude protein (as is) and the crude protein consists of 20% protein/peptide, 20% free amino acids (mainly glutamic acid) and 60% non-protein nitrogen (NPN), mainly in the form of ammonium chloride. Proteoferm is also a rich source of some other minerals, particularly sodium and potassium. There are several reasons that Proteoferm may have value as a feed ingredient in diets of beef cattle: 1) Beef cattle can utilize significant levels of NPN as a source of dietary protein; 2) Residual monosodium glutamate in Proteoferm may serve to enhance flavor of the diet and stimulate increased feed intake; and 3) Addition of higher moisture feeds often facilitates diet mixing and promotes improved feed intakes. Given these possibilities, a feeding trial was conducted with growing heifer calves to evaluate the potential of Proteoferm as a feed ingredient. The objectives of this study were: 1) to evaluate the effect of Proteoferm on palatability (feed intake) and performance of growing beef cattle, and 2) to compare Proteoferm as a source of NPN and energy to isonitrogenous mixtures of molasses and urea in beef cattle diets.

MATERIALS AND METHODS

Ninety Angus-cross growing heifers with an average initial body weight of 244 kg were used. Heifers were vaccinated for IBR, PI₃, blackleg, malignant edema and Hemophilus. They were dewormed and treated for grubs and lice. Heifers were weighed and allotted to 15 pens (6 heifers/pen). Three pens were then randomly allotted to each of five experimental diets.

Diets (Table 1) were based on corn silage and medium-quality grass hay and were formulated to contain 2.40 to 2.50 Mcal ME/kg of dry matter (DM). The remainder of the diets consisted of ground corn and supplemental sources of protein, minerals, and vitamins. Soybean meal provided supplemental protein (preformed amino acids) to the control diet. In the Proteoferm diets (i.e., 3% Prot and 5% Prot), Proteoferm was added at 3 and 5% of dietary DM, respectively. The 3 and 5% Proteoferm levels provided, respectively, 22 and 33% of total dietary CP as NPN and were selected because they fall within the recommended levels of NPN supplementation of beef cattle diets (NRC, 1984). The 5% proteoferm level was included to evaluate any additional effects of a higher level of Proteoferm on feed intake. No additional response to NPN itself was anticipated. The molasses-urea diets (i.e., 3% Mol-U and 5% Mol-U) contained 3 and 5%, respectively, of a molasses-urea mixture formulated to be isonitrogenous to Proteoferm. Three diets (i.e., control, 3% Prot, and 3% Mol-U) were formulated for 11.5% CP on a DM basis. This is slightly less than the requirements (NRC, 1984) for these cattle and allowed for more sensitive evaluation of differences in performance due to source of dietary CP. The

remaining diets (i.e., 5% Prot and 5% Mol-U) provided 12.8% CP on a DM basis.

Heifers were weighed at the beginning of the trial and interim weights were taken every 28 days. At the end of an 84-day feeding trial, heifers were weighed on two consecutive days to help reduce variation created by variation in gut fill. Feed intake was monitored daily and adjusted to maintain *ad libitum* intakes while minimizing feed refusals.

After the completion of the trial, average daily gain (ADG), daily DM intake, and gain/feed ratio were calculated for each pen. Performance data were analyzed by analysis of variance (SAS, 1985) for a completely randomized design with pen as the experimental unit. Planned treatment comparisons included the following orthogonal contrasts: 1) control vs 3% Prot, 3% Mol-U, 5% Prot, and 5% Mol-U (i.e., control vs NPN supplementation), 2) control vs 3% Prot and 3% Mol-U (i.e., control vs NPN at same dietary CP level), 3) 3% Prot and 3% Mol-U vs 5% Prot and 5% Mol-U (i.e., 3% level vs 5% level), and 4) 3% Prot and 5% Prot vs 3% Mol-U and 5% Mol-U (i.e., Proteoform vs molasses-urea).

RESULTS AND DISCUSSION

Neither interim (data not shown) nor cumulative (Table 2) performance of heifers was affected ($P > .10$) by CP level or source in the diet. Therefore, planned treatment comparisons were not made. For the entire 84 day trial (Table 2), there were no differences ($P > .10$) among diets in any of the performance parameters evaluated (i.e., ADG, daily DM intake, and gain/feed ratio). Mean values for all treatments were almost identical. Average values across diets for ADG (kg), daily DM intake (kg), and gain/feed ratio were 0.91, 6.69 and .136, respectively. Rates of gain were very near to those that would be predicted for this type of animal fed a diet with an energy content similar to that estimated for the control diet.

Results indicate that Proteoform, when fed at these levels, did not have any stimulatory effect on feed intake nor did it provide any other apparent advantages in comparison to an isonitrogenous mixture of molasses and urea. It may be that higher levels of Proteoform are necessary to provide a stimulatory effect on feed intake. One reason that it probably has limited potential for enhancing performance is its negligible value as an energy source. The gross energy value of Proteoform was 2.55 kcal/g DM (by bomb calorimetry) and most of this is probably accounted for by the heat of combustion of the ammonia in the Proteoform. It is concluded from our results that, for growing cattle, Proteoform can be fed at 3 to 5% of the dietary DM without any negative effects on feed intake or performance. Other uses and opportunities for Proteoform should be investigated.

REFERENCES

NRC. 1984. Nutrient Requirements of Beef Cattle (6th Rev. Ed.). National Academy Press, Washington, DC.

SAS. 1985 SAS User's Guide: Statistics. SAS Inst. Inc., Cary, NC.

TABLE 1. COMPOSITION OF DIETS FED TO GROWING HEIFERS

Ingredient	Diet ^a				
	Control	3% Prot	3% Mol-U	5% Prot	5% Mol-U
----- % of DM -----					
Corn silage	56.0	59.1	59.1	57.9	57.9
Grass hay	34.0	30.9	30.9	30.1	30.1
Ground corn	3.78	4.92	4.92	4.92	4.92
Soybean meal	4.14	--	--	--	--
Rumensin mix ^b	2.08	2.08	2.08	2.08	2.08
Proteoform	--	3.0	--	5.0	--
Molasses	--	--	2.28	--	3.8
Urea	--	--	.72	--	1.2
Nutrient profile ^c :					
ME, Mcal/kg	2.53	2.44	2.50	2.39	2.50
CP, %	11.5	11.5	11.5	12.8	12.8
Ca, %	.85	.83	.85	.83	.86
P, %	.39	.36	.36	.36	.35
K, %	1.82	1.74	1.75	1.75	1.76

^aProt= Proteoform; Mol-U= a mixture of molasses and urea that is isonitrogenous to Proteoform; Proteoform or the molasses-urea mixture were added at 3 or 5% of dietary dry matter (DM).

^bProvided 25 g monensin/ton of DM and also provided supplemental calcium, phosphorus and vitamins A, D, and E.

^cOn a DM basis.

TABLE 2. FEEDLOT PERFORMANCE OF GROWING HEIFERS AS AFFECTED BY DIETARY PROTEIN SOURCE AND LEVEL

Item	Diet ^{ab}					SEM ^c
	Control	3% Prot	3% Mol-U	5% Prot	5% Mol-U	
No. of heifers	18	18	18	18	18	
Initial weight, kg	241	247	242	243	247	1.6
ADG ^d , kg	.91	.92	.93	.92	.89	.038
DM intake, kg/d	6.61	6.68	6.66	6.65	6.91	.219
Gain/feed ratio	.138	.138	.140	.138	.128	.006

^aProt = Proteoform; Mol-U = a mixture of molasses and urea that is isonitrogenous to Proteoform; Proteoform or the molasses-urea mixture were added at 3 or 5% of dietary dry matter (DM).

^bTreatment effects were not significant ($P > .10$) for any of the measurements evaluated.

^cStandard error of the mean.

^dADG = average daily gain.

EFFECT OF IMPLANT SOURCE AND DIETARY CRUDE PROTEIN LEVEL ON FEEDLOT PERFORMANCE AND CARCASS CHARACTERISTICS OF FINISHING BEEF HEIFERS

H. S. Hussein, L. L. Berger and T. G. Nash

SUMMARY

Sixty-nine Angus-cross heifers with an average initial body weight of 353 kg were used in a 2 x 2 factorial arrangement of treatments to determine the effect of implant source, dietary CP level, and their interaction on feedlot performance and carcass characteristics. At the beginning of the 89-day finishing trial, heifers were allotted to 12 pens (5 or 6 heifers/pen) and implanted with Synovex H or Finaplix H. Three pens of each implant treatment were fed *ad libitum* corn-based finishing diets containing (on a DM basis) 12.3% CP (1% urea) or 14.7% CP (1% urea + 5.5% soybean meal). No interactions ($P > .10$) were observed for feedlot performance or carcass characteristics. Results indicated that daily dry matter intake, average daily gain and gain/feed were not affected ($P > .10$) by implant source or dietary CP level. However, heifers were more efficient ($P < .10$) in utilizing protein for gain (unit of gain per unit of CP intake) when fed the lower CP diet (1.29 vs 1.06). Carcass data indicated that hot carcass weight (kg), kidney, pelvic and heart fat (%), marbling score, or USDA choice carcasses (%) were not affected ($P > .10$) by implant source. Heifers implanted with Synovex H had higher ($P < .10$) dressing percent (61.8 vs 59.8), greater ($P < .10$) ribeye area (78.0 vs 73.2 cm²), less ($P < .10$) backfat (1.12 vs 1.34 cm), and better ($P < .10$) yield grade (2.7 vs 3.1) than those implanted with Finaplix H. Except for backfat thickness, carcass characteristics were not affected ($P > .10$) by dietary CP level. Heifers fed the low CP level had thinner ($P < .10$) backfat (1.14 vs 1.32 cm) than those fed the high CP level. Results suggest that the protein requirements of finishing heifers were met at the 12.3% level and Synovex H was superior ($P < .10$) to Finaplix H in producing carcasses that had higher dressing percent, greater ribeye area, less backfat, and better yield grade.

INTRODUCTION

The response of finishing heifers to anabolic implants such as Synovex H (200 mg testosterone propionate and 20 mg estradiol benzoate) or Finaplix H (200 mg trenbolone acetate) have been variable. Goodman et al. (1982) indicated that finishing heifers implanted with Synovex H had similar ($P > .05$) average daily gain (ADG) to the nonimplanted heifers. Synovex H implanted heifers gave carcasses with 6.3% heavier ($P < .05$) hot weight and 10.2% greater ($P < .05$) ribeye area (REA). In contrast, Reiling et al. (1993) reported that implantation of first-calf heifers with Synovex H enhanced ($P < .10$) ADG and gain/feed ratio by 10% over the nonimplanted heifers with no improvement ($P > .10$) in carcass characteristics. Results of a comparative study by Eck and Corah (1993) indicated that finishing heifers implanted with Synovex H had higher ($P < .05$) ADG than heifers either implanted with Finaplix H or nonimplanted. Heifers implanted with Finaplix H had similar ($P > .05$) ADG to those nonimplanted. Implanted heifers had heavier ($P < .05$) carcasses and larger ($P < .05$) REA compared to nonimplanted heifers.

Other carcass measurements did not differ ($P > .05$) among treatments. Trenkle (1993) studied the relationship between dietary CP level and implant. Finishing heifers were either implanted with Synovex H and Finaplix H or nonimplanted and were fed diets containing 9.5, 11.7% CP (from urea supplement), or 14.0% CP (from urea-soybean supplement). Implant improved ($P < .05$) ADG over the control by 12.8 to 20% and increased ($P < .05$) REA. Both CP level and implant increased ($P < .05$) hot carcass weight but did not affect ($P > .05$) USDA choice carcasses. The objective of the present study was to evaluate the effect of implant source (i.e., Synovex H or Finaplix H), dietary crude protein (CP) level (12.3 or 14.7% on a DM basis), and their interaction on feedlot performance and carcass characteristics of finishing heifers.

MATERIALS AND METHODS

Sixty-nine Angus-cross heifers with an average initial body weight of 353 kg were used in an 89-day finishing trial. Heifers were weighed and allotted to 12 pens (5 or 6 heifers/pen) and pens were allotted randomly to treatments. Heifers were implanted with Synovex H or Finaplix H once (6 pens/implant) on day 1 of the trial. Three pens of each implant treatment were fed *ad libitum* corn-based finishing diets (Table 1) containing (on a DM basis) 12.3% CP (1% urea) or 14.7% CP (1% urea + 5.5% soybean meal). Diets were formulated to meet or exceed the requirements (i.e., CP, Ca, P, K, trace minerals, and vitamins) recommended by the NRC (1984) for those heifers.

Heifers were weighed on day 32, 61, 88 and 89. Final weights were calculated as the average of full weights on two consecutive days (i.e., day 88 and day 89). At the end of the trial, heifers were slaughtered in a commercial packing plant and their carcasses were evaluated by University of Illinois personnel at 24 h postmortem.

Feedlot performance data were calculated for each pen but carcass data were collected for each individual animal. Data were analyzed as a completely randomized design using the GLM procedures of SAS (1985) with pen as the experimental unit for feedlot performance and animal as the experimental unit for carcass characteristics. Because treatments were arranged as a 2 x 2 factorial, treatment sums of squares were separated into the main effects (implant source and dietary CP level) and their interaction. When the F-test was found to be significant ($P < .10$), the treatment means were separated by Fisher's least significant difference (Fisher, 1949).

RESULTS AND DISCUSSION

No interactions ($P > .10$) were observed for feedlot performance or carcass characteristics. Therefore, results of the main effects (implant source and dietary CP level) are presented in Tables 2 and 3.

Interim performance (daily DM intake, ADG, or gain/feed) of heifers (data not shown) was not affected ($P > .10$) by either implant source or dietary CP level. However, protein efficiency ratio (unit of gain per unit of CP intake) was higher ($P < .10$) for heifers fed the 12.3% CP vs the 14.7% CP diets (1.30 vs 1.14, 1.07 vs .89, and 1.49 vs 1.15 for day 1-32,

day 33-61, and day 62-89, respectively). The cumulative performance of heifers during the entire 89-day trial is presented in Table 2. Results indicated that daily DM intake, ADG, and gain/feed were not affected ($P > .10$) by implant source or dietary CP level. However, similar to Trenkle's findings (1993), increasing dietary CP level (Table 2) resulted in a 7.5% increase ($P > .10$) in daily DM intake and a 6.2% improvement ($P > .10$) in ADG. Heifers were more efficient ($P < .10$) in utilizing protein for gain (unit of gain per unit of CP intake) when fed the lower CP diet (1.29 vs 1.06).

Carcass characteristics of heifers are summarized in Table 3. Results indicated that hot carcass weight (kg), kidney, pelvic and heart fat (%), marbling score, or USDA choice carcasses (%) were not affected ($P > .10$) by either implant source or dietary CP level. Heifers implanted with Synovex H had higher ($P < .10$) dressing percentage (61.8 vs 59.8), greater ($P < .10$) REA (78.0 vs 73.2 cm²), less ($P < .10$) backfat (1.12 vs 1.34 cm), and better ($P < .10$) yield grade (2.7 vs 3.1) than those implanted with Finaplix H. Dietary CP level did not exert any effect ($P > .10$) on carcass characteristics except for backfat thickness. Heifers fed the low CP level had thinner ($P < .10$) backfat (1.14 vs 1.32 cm) than those fed the high CP level.

Results suggest that the CP requirements of finishing heifers were met at the 12.3% level and Synovex H was superior ($P < .10$) to Finaplix H in producing carcasses that have higher dressing percent, greater ribeye area, less backfat, and better yield grade.

REFERENCES

- Eck, T. P. and L. R. Corah. 1993. Implant comparisons in feedlot steers and heifers. *J. Anim. Sci.* 71(Suppl. 1):53 (Abstr.).
- Fisher, R. A. 1949. *The Design of Experiments*. Oliver and Boyd Ltd., Edinburgh.
- Goodman, J. P., A. L. Slyter and L. B. Embry. 1982. Effect of intravaginal devices and Synovex-H implants on feedlot performance, cyclic activity and reproductive tract characteristics of beef heifers. *J. Anim. Sci.* 54:491.
- NRC. 1984. *Nutrient Requirements of Beef Cattle* (6th Rev. Ed.). National Academy Press, Washington, DC.
- Reiling, B. A., L. L. Berger, F. K. McKeith and D. B. Faulkner. 1993. Effects of age, prenatal androgenization, MGA, and Synovex H implants on growth, carcass, and sensory traits of open and early weaned first-calf heifers. *J. Anim. Sci.* 71(Suppl. 1):46 (Abstr.).
- SAS. 1985. *SAS User's Guide: Statistics*. SAS Inst. Inc., Cary, NC.
- Trenkle, A. 1993. Protein requirement of finishing yearling heifers implanted with Synovex H and Finaplix H. *Beef-Sheep Research Rep.*, Iowa State University, Ames. pp 158-160.

TABLE 1: COMPOSITION OF DIETS FED TO FINISHING HEIFERS

Ingredient	Dietary crude protein level ^a	
	12.3%	14.7%
	----- % of DM -----	
Whole shelled corn	52.0	46.5
Corn flour	20.0	20.0
Corn silage	12.0	12.0
Condensed distillers solubles	8.0	8.0
Supplement ^b	8.0	8.0
Soybean meal	0.0	5.5

^aPercentage of dry matter (DM).

^bContaining (on a DM basis) ground corn (69.3%), urea (12.3%), limestone (9.6%), trace mineralized salt (3.5%), pot chloride (2.5%), dicalcium phosphate (2.2%), vitamin (A, D, E and K) premix (0.1%), Monensin (0.3%), and thiamine (0.2%).

TABLE 2: EFFECT OF IMPLANT SOURCE AND DIETARY PROTEIN LEVEL ON FEEDLOT PERFORMANCE OF FINISHING HEIFERS

Item	Implant source		CP level ^a , %		SEM ^b
	Synovex	Finaplix	12.3	14.7	
No. of heifers	35	34	35	34	
Initial weight, kg	348.31	357.03	348.67	356.67	3.74
Dry matter intake, kg/d	8.33	8.56	8.14	8.75	.32
Average daily gain, kg	1.37	1.29	1.29	1.37	.06
Gain/feed ratio	.165	.154	.159	.156	.006
Protein efficiency ratio ^c	1.23	1.25	1.29 ^d	1.06 ^e	.05

^aCrude protein (% of dietary DM).

^bStandard error of the mean.

^cUnit of gain per unit of crude protein intake.

^{d,e}Means in the same row with different superscript letters differ ($P < .10$).

TABLE 3: EFFECT OF IMPLANT SOURCE AND DIETARY PROTEIN LEVEL ON CARCASS CHARACTERISTICS OF FINISHING HEIFERS

Item	Implant source		CP level ^a , %		SEM ^b
	Synovex	Finaplix	12.3	14.7	
No. of heifers	35	34	35	34	
Full live weight ^c , kg	470.10	471.63	463.17	478.56	7.42
Hot carcass weight, kg	290.3	283.1	280.2	293.2	5.77
Dressing percent	61.8 ^d	59.8 ^e	60.4	61.2	.53
Backfat thickness, cm	1.12 ^e	1.34 ^d	1.14 ^e	1.32 ^d	.07
Ribeye area, cm ²	78.0 ^d	73.2 ^e	75.2	76.0	1.14
Kidney, pelvic, & heart fat, %	2.7	2.7	2.8	2.6	.07
Yield grade ^f	2.7 ^e	3.1 ^d	2.8	3.0	.11
Marbling score ^g	1110.0	1132.1	1117.9	1124.1	18.0
USDA choice carcasses, %	85.8	94.1	88.7	91.2	5.3

^aCrude protein (% of dietary DM).

^bStandard error of the mean.

^cAverage of two full weights on two consecutive days.

^{d,e}Means in the same row for same main effect with different superscript letters differ (P < .10).

^fYield grade = 2.5 + (2.5 X adjusted fat thickness) + (.0038 X hot carcass weight) + (.2 X kidney, pelvic & heart fat) - (.32 X ribeye area).

^g1000 = choice⁻, 1100 = choice⁰, 1200 = choice⁺.

IN VITRO FIBER DIGESTION OF FORAGES AND FIBER-CONTAINING BYPRODUCTS AS AFFECTED BY COBALT GLUCOHEPTONATE SUPPLEMENTATION

H. S. Hussein, G. C. Fahey, Jr., B. W. Wolf, and L. L. Berger

SUMMARY

Cobalt glucoheptonate as a source of cobalt to enhance ruminal fiber digestion was evaluated in two in vitro digestibility experiments. In Experiment 1, cobalt supplementation was evaluated under two dietary conditions. Treatments were arranged as a 2 x 5 x 3 x 2 factorial. Two inocula (ruminal fluid from steers fed *ad libitum* alfalfa hay or a high concentrate diet; 2 steers per diet) were used. Five substrates (alfalfa leaf, alfalfa stem, orchardgrass leaf, orchardgrass stem, and ground corn) were incubated with 3 levels of cobalt (0, 5, and 10 mg/kg substrate DM) for 2 fermentation periods (24 and 48 h). In Experiment 2, one source of inoculum (from steers fed alfalfa hay) was used. Treatments were arranged as a 5 x 4 x 2 factorial. Five substrates including 2 forages (alfalfa hay and orchardgrass hay) and 3 fiber-containing byproducts (corn cobs, recycled hydrochloric acid-treated newsprint, and cellulose casing from the meat processing industry) were incubated with 4 levels of cobalt (0, 10, 20, and 30 mg/kg substrate DM) for 2 fermentation periods (24 and 48 h). Interactions ($P > .05$) were not observed between the cobalt level supplemented and any of the main effects studied or their interactions for DM, OM, or NDF digestibilities. In Experiment 1, in vitro DM, OM, and NDF digestibilities were 17.0, 19.5, and 40.5% higher ($P < .05$), respectively, when inoculum from alfalfa-fed steers vs concentrate-fed steers was used. Digestibilities of DM, OM, and NDF were higher ($P < .05$) for leaf vs stem fractions. Ground corn had the highest ($P < .05$) digestibilities of DM and OM. In Experiment 2, digestibilities of DM, OM, and NDF were highest ($P < .05$) for alfalfa hay and lowest ($P < .05$) for recycled hydrochloric acid-treated newsprint. Digestibilities of OM and NDF of corn cobs were similar to those of orchardgrass hay but were 27.1 and 41.6% higher ($P < .05$), respectively, than those of cellulose casing. Results of both experiments indicated that increasing cobalt level above minimum animal requirements did not improve DM, OM, or fiber digestion.

INTRODUCTION

Supplementation of cobalt above minimum animal requirements may be beneficial during periods of rapid ruminal fermentation where increased microbial numbers require greater amounts of vitamin B₁₂ than do less active fermentations. Production of vitamin B₁₂ in the rumen depends primarily on cobalt and the roughage content of the diet. Cobalt supplementation may improve ruminal fiber digestion by enhancing bacterial activity. For example, divalent cations (e.g., cobalt) may act as a bridge between the bacteria and plant cell walls, both of which tend to be negatively charged. When a negatively charged bacterium has difficulty attaching to similarly charged fiber particles, a divalent cation, possessing two positive charges, could serve as a link between the two negatively charged surfaces. The addition of divalent cations, including cobalt, in greater than the recommended amounts to the diet tended to improve fiber digestion (Lopez-Guisa and

Satter, 1992; Zelenak et al., 1992). Given this potential of cobalt, two in vitro digestibility experiments were conducted to evaluate cobalt glucoheptonate (as a source of cobalt) supplementation on digestion of a wide range of fiber-containing substrates. In Experiment 1, the objectives were: 1) to determine the effects of different levels (0, 5, and 10 ppm) of cobalt supplementation on in vitro dry matter (DM), organic matter (OM), and neutral detergent fiber (NDF) digestion of the leaf and stem fractions of different forages (alfalfa and orchardgrass), and 2) to evaluate such supplementation under different dietary conditions (all forage vs all concentrate diets fed to donor animals). In Experiment 2, the objective was to determine the effects of higher levels (0, 10, 20, and 30 ppm) of cobalt supplementation than those used in Experiment 1 on in vitro DM, OM, and NDF digestion of different forages (alfalfa and orchardgrass) and different fiber-containing byproducts (corn cobs, recycled hydrochloric acid-treated newsprint, and cellulose casing).

MATERIALS AND METHODS

Animals and Diets: In Experiment 1, four ruminally cannulated steers were used as donors of ruminal fluid for the in vitro fermentation. The steers were assigned randomly to two experimental diets that were fed *ad libitum* for an adaptation period of 21 d. Two steers were fed an all forage (alfalfa hay) diet and the other two were fed a concentrate diet (containing 25% corn flour, 5% corn silage, 32% high moisture corn, 25% corn gluten feed, 5% condensed distillers solubles, and 8% commercial protein supplement on a DM basis). In Experiment 2, two ruminally cannulated steers were used and were fed an all alfalfa diet *ad libitum* for 21 d.

Substrates: In Experiment 1, one legume (alfalfa) hay and one grass (orchardgrass) hay were used. To determine the type of fiber most affected by cobalt supplementation, both were separated into leaf and stem fractions. Ground corn also was used as a substrate. In Experiment 2, two forages (alfalfa hay and orchardgrass hay) and three fiber containing byproducts including corn cobs, recycled 4% hydrochloric acid-treated newsprint (Wolf, 1993), and cellulose casing from the meat processing industry were used. The chemical composition of the substrates is shown in Table (1). Ground (1 mm) substrates were weighed into the centrifuge tubes. The amount of substrate used was .5 g DM/tube in Experiment 1 and .4 g DM/tube in Experiment 2. Soybean meal (.1 g DM) was added to all tubes (including blanks) in Experiment 2 to assure that amino acid and small peptide requirements by the ruminal cellulolytic bacteria were met, especially for those substrates which contain no protein (i.e., corn cobs, recycled hydrochloric acid-treated newsprint, and cellulose casing).

Cobalt Levels: Cobalt glucoheptonate ($C_{14}H_{26}O_{16}Co \cdot XH_2O$) was dissolved in distilled water and the solution was analyzed for cobalt by atomic absorption spectrophotometry. An aliquot of the cobalt glucoheptonate solution was added directly to all tubes prior to inoculation. Cobalt levels were 0, 5, and 10 mg Co/kg DM of the substrate (i.e., 0, 5, and 10 ppm) in Experiment 1 and were 0, 10, 20, or 30 mg Co/kg DM of the substrate (i.e., 0, 10, 20, and 30 ppm) in Experiment 2.

Inoculum and Fermentation: The ruminal fluid was collected from the steers 4 h post-

feeding on d 21 of the adaptation period in each experiment and strained through 8 layers of cheesecloth. The ruminal fluid from each steer was mixed (on an equal volume basis) with McDougall's buffer (with CO₂ bubbling) and 30 ml of the inoculum were added to each tube (containing a substrate or a blank) assigned for each steer. Tubes were flushed with CO₂, capped with stoppers equipped with one-way gas release valves, and placed in an incubator at 39°C. Procedures were according to Tilley and Terry (1963). Two time periods of fermentation were evaluated (24 vs 48 h) in both experiments. Fermentation was stopped by storing tubes at 5°C for 2 h prior to processing.

Analytical Procedures: In Experiment 1, 576 centrifuge tubes were used (288 tubes were analyzed for DM and OM and 288 tubes were analyzed for NDF). Concentrations of volatile fatty acids (VFA) were measured in aliquots of tubes used for DM and OM determinations. In Experiment 2, 384 centrifuge tubes were used (192 tubes were analyzed for DM and OM and 192 tubes were analyzed for NDF). Neutral detergent fiber was measured according to the procedure of Jeraci et al. (1988) except that an additional 50 ml of NDF solution was necessary to accommodate the 30 ml solution in the tubes without changing the pH of the NDF solution. Concentrations of VFA were measured on a gas chromatograph after preparing the samples according to the procedure of Erwin et al. (1961). Samples of ruminal fluid used in both experiments were centrifuged at 20,000 X g to remove feed particles and both ruminal protozoa and bacteria. The supernatant then was removed and its cobalt concentration was determined by atomic absorption spectrophotometry.

Statistical Analyses: Dry Matter, OM and NDF digestibility data and VFA concentration data were analyzed as a completely randomized design using the GLM procedures of SAS (1985). Because treatments in Experiment 1 were arranged as a 2 X 5 X 3 X 2 factorial, treatment sums of squares were separated into main effects (2 inoculum sources, 5 substrate sources, 3 cobalt levels, and 2 fermentation times) and their corresponding interactions. Similarly, because treatments in Experiment 2 were arranged as a 5 X 4 X 2 factorial, treatment sums of squares were separated into main effects (5 substrate sources, 4 cobalt levels, and 2 fermentation times) and their corresponding interactions. When the F-test was found to be significant ($P < .05$), treatment means were compared using Fisher's least significant difference (Fisher, 1949). Orthogonal contrasts also were used to test for linear and quadratic responses to cobalt supplementation (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Cobalt concentration of ruminal fluid used for the in vitro fermentations was .01 mg Co/liter of ruminal fluid, irrespective of diet fed to the animal.

No significant interactions ($P > .05$) between cobalt level supplemented and any of the other main effects studied or their interactions were observed for in vitro DM, OM, or NDF digestibility in either experiment or for VFA concentrations in Experiment 1.

Experiment 1: Results summarizing the main effects studied (i.e., cobalt, inoculum,

substrate, and fermentation time) are presented in Tables 2, 3, 4, 5, and 6. Cobalt supplementation (Table 2) did not improve ($P > .05$) digestibility of DM, OM, or NDF. Table 3 shows that increasing cobalt level to 5 or 10 ppm did not affect ($P > .05$) concentrations (mM) of VFA or their molar proportions. In vitro digestibilities (Table 4) were improved ($P < .05$) by 17.0, 19.5, and 40.5% for DM, OM, and NDF, respectively, when the substrates were incubated with inoculum obtained from steers fed the alfalfa diet vs the concentrate diet. Digestibilities of DM, OM, and NDF (Table 5) were higher ($P < .05$) for leaves than for stems and for alfalfa vs orchardgrass. Ground corn had the highest ($P < .05$) DM, OM, and NDF digestibilities compared to the other substrates. However, NDF digestibility of corn was not different ($P > .05$) from NDF digestibility of leaves of either alfalfa or orchardgrass. Digestibilities of DM, OM, and NDF (Table 6) were 29.2 to 31.9% greater ($P < .05$) for the 48-h than for the 24-h fermentation time.

Experiment 2: Cobalt supplementation was evaluated at higher levels (i.e., 20 and 30 ppm) while maintaining the 0 and the 10 ppm levels studied in Experiment 1 for comparison. Results (Table 4) of Experiment 1 indicated an improvement in DM, OM, and NDF digestion due to utilization of inoculum obtained from alfalfa-fed steers vs concentrate-fed steers. Therefore, in Experiment 2, only inoculum from steers fed the alfalfa diet was used. Results summarizing the main effects studied (i.e., cobalt, substrate, and fermentation time) are presented in Tables 7, 8, and 9. Cobalt supplementation (Table 7) did not improve ($P > .5$) DM, OM, or NDF digestibilities. In vitro DM, OM, and NDF digestibilities (Table 8) were highest ($P < .05$) for alfalfa hay and lowest ($P < .05$) for recycled hydrochloric acid-treated newsprint. Digestibilities of OM and NDF of corn cobs were comparable to those of orchardgrass hay but were 27.1 and 41.6% higher ($P < .05$) than those of cellulose casing. Digestibilities (Table 9) were 55.5 to 70.5% greater ($P < .05$) for the 48-h than for the 24-h fermentation time.

Results indicated that increasing cobalt levels (ppm) above the minimum requirements (.1 ppm) recommended by the NRC for sheep (1985), beef cattle (1984), or dairy cattle (1988) did not improve ($P > .05$) in vitro DM, OM, or fiber digestion in either experiment.

REFERENCES

- Erwin, E. S., G. J. Macro and E. M. Emery. 1961. Volatile fatty acid analysis of blood and rumen fluid by gas chromatography. *J. Dairy Sci.* 44:1768.
- Fisher, R. A. 1949. *The Design of Experiments.* Oliver and Boyd Ltd., Edinburgh.
- Jeraci, J. L., T. Hernandez, J. B. Robertson and P. J. Van Soest. 1988. New and improved procedure for neutral-detergent fiber. *J. Anim. Sci.* 66(Suppl. 1):351 (Abstr.).
- Lopez-Guisa, J. M. and L. D. Satter. 1992. Effect of copper and cobalt addition on digestion and growth in heifers fed diets containing alfalfa silage or corn crop residues. *J. Dairy Sci.* 75:247.

- NRC. 1984. Nutrient Requirements of Beef Cattle (6th Rev. Ed.). National Academy Press, Washington, DC.
- NRC. 1985. Nutrient Requirements of Sheep (6th Ed.). National Academy Press, Washington, DC.
- NRC. 1988. Nutrient Requirements of Dairy Cattle (6th Rev. Ed.). National Academy Press, Washington, DC.
- SAS. 1985. SAS User's Guide: Statistics. SAS Inst. Inc., Cary, NC.
- Steel, R. G. D. and J. H. Torrie. 1980. Principles and Procedures of Statistics: A Biometrical Approach (2nd Ed.). McGraw Hill Book Co., New York.
- Tilley, J. M. A. and R. A. Terry. 1963. A two stage technique for the in vitro digestion of forage crops. J. Br. Grassl. Soc. 18:104.
- Wolf, B. W. 1993. Chemically treated, recycled newsprint as an energy source for ruminants. M.S. Thesis. University of Illinois, Urbana.
- Zalenak, I., D. Jalc, I. Placha, P. Sviatko, T. Vendrak, P. Siroka and F. Gyulai. 1992. The effect of copper and cobalt supplementation on the digestibility of fibrous feeds in sheep. Vet. Med. (Prague) 37:221.

TABLE 1: CHEMICAL COMPOSITION OF SUBSTRATES INCUBATED IN VITRO

Substrate	% of DM			Co, ppm ^d
	OM	CP	NDF	
Experiment 1:				
Alfalfa leaf	88.7	28.6	30.9	.42
Alfalfa stem	93.4	11.7	67.0	.29
Orchardgrass leaf	87.6	12.6	69.3	.36
Orchardgrass stem	93.1	3.8	81.5	.22
Ground corn	98.7	8.6	9.9	.08
Experiment 2:				
Alfalfa hay	91.9	17.2	53.9	.31
Orchardgrass hay	89.6	9.2	73.7	.27
Corn cobs	98.5	2.2	90.6	.11
HCl-newsprint ^a	97.8	.4	76.4	ND ^e
Cellulose casing ^b	100.0	1.4	90.1	ND
Soybean meal ^c	93.4	51.3	14.3	ND

^aRecycled hydrochloric acid-treated newsprint (4% HCl on a newsprint DM basis).

^bA byproduct of the meat processing industry.

^cA protein supplement added to substrates in Experiment 2.

^dmg cobalt/kg DM substrate.

^eNot determined.

TABLE 2: EFFECT OF COBALT SUPPLEMENTATION ON IN VITRO DIGESTIBILITY OF DM, OM, AND NDF ACROSS SUBSTRATES (EXPERIMENT 1)

Cobalt level ^a , ppm	Digestibility, %		
	DM	OM	NDF
0	47.0	44.9	38.2
5	47.8	45.6	40.4
10	46.8	44.8	39.0
SEM ^b	.6	.6	1.6

^appm = mg cobalt (from cobalt glucoheptonate)/kg substrate DM.

^bStandard error of the mean.

TABLE 3: EFFECT OF COBALT SUPPLEMENTATION ON IN VITRO VOLATILE FATTY ACID CONCENTRATIONS ACROSS SUBSTRATES (EXPERIMENT 1)

Item	Cobalt level ^a , ppm			SEM ^b
	0	5	10	
Total VFA, mM	59.9	56.4	56.5	1.8
----- mol/100 mol -----				
Acetate	59.7	59.6	60.1	.7
Propionate	27.9	27.5	26.7	.9
Butyrate	8.7	8.9	9.0	.4
Isobutyrate	.7	.6	.7	.1
Valerate	2.1	2.4	2.5	.1
Isovalerate	.9	1.0	1.0	.1

^appm = mg cobalt (from cobalt glucoheptonate)/kg substrate DM.

^bStandard error of the mean.

TABLE 4: EFFECT OF INOCULUM SOURCE ON IN VITRO DIGESTIBILITY OF DM, OM, AND NDF ACROSS SUBSTRATES (EXPERIMENT 1)

Inoculum source	Digestibility, %		
	DM	OM	NDF
Alfalfa	50.9 ^b	49.1 ^b	45.8 ^b
Concentrate	43.5 ^c	41.1 ^c	32.6 ^c
SEM ^a	.5	.5	1.3

^aStandard error of the mean.

^{b,c}Means in the same column with different superscript letters differ ($P < .05$).

TABLE 5: EFFECT OF SUBSTRATE SOURCE ON IN VITRO DIGESTIBILITY OF DM, OM, AND NDF (EXPERIMENT 1)

Substrate source	Digestibility, %		
	DM	OM	NDF
Alfalfa leaf	48.3 ^c	48.2 ^c	50.1 ^b
Alfalfa stem	44.9 ^d	42.5 ^d	33.9 ^d
Orchardgrass leaf	42.3 ^e	39.4 ^e	43.7 ^c
Orchardgrass stem	30.7 ^f	26.6 ^f	21.4 ^e
Ground corn	69.6 ^b	68.8 ^b	46.9 ^{bc}
SEM ^a	.7	.8	2.2

^aStandard error of the mean.

^{b,c,d,e,f}Means in the same column with different superscript letters differ ($P < .05$).

TABLE 6: EFFECT OF FERMENTATION TIME ON IN VITRO DIGESTIBILITY OF DM, OM, AND NDF ACROSS SUBSTRATES (EXPERIMENT 1)

Fermentation time, h	Digestibility, %		
	DM	OM	NDF
24	40.8 ^c	38.9 ^c	34.2 ^c
48	53.5 ^b	51.3 ^b	44.2 ^b
SEM ^a	.5	.5	1.3

^aStandard error of the mean.

^{b,c}Means in the same column with different superscript letters differ ($P < .05$).

TABLE 7: EFFECT OF COBALT SUPPLEMENTATION ON IN VITRO DIGESTIBILITY OF DM, OM, AND NDF ACROSS SUBSTRATES (EXPERIMENT 2)

Cobalt level ^a , ppm	Digestibility, %		
	DM	OM	NDF
0	36.3	34.4	28.7
10	36.5	34.9	28.0
20	36.0	35.1	27.0
30	37.7	35.4	28.6
SEM ^b	.9	.8	.9

^appm = mg cobalt (from cobalt glucoheptonate)/kg substrate DM.

^bStandard error of the mean.

TABLE 8: EFFECT OF SUBSTRATE SOURCE ON IN VITRO DIGESTIBILITY OF DM, OM, AND NDF (EXPERIMENT 2)

Substrate source	Digestibility, %		
	DM	OM	NDF
Alfalfa hay	53.3 ^d	51.6 ^d	41.0 ^d
Orchardgrass hay	42.6 ^e	37.8 ^e	36.6 ^e
Corn cobs	37.6 ^f	37.0 ^e	35.4 ^e
HCl-newsprint ^a	19.3 ^h	19.1 ^g	2.3 ^g
Cellulose casing ^b	30.4 ^g	29.1 ^f	25.0 ^f
SEM ^c	1.0	.9	1.0

^aRecycled hydrochloric acid-treated newsprint (4% HCl on a newsprint DM basis).

^bA byproduct of the meat processing industry.

^cStandard error of the mean.

^{d,e,f,g,h}Means in the same column with different superscript letters differ (P < .05).

TABLE 9: EFFECT OF FERMENTATION TIME ON IN VITRO DIGESTIBILITY OF DM, OM, AND NDF ACROSS SUBSTRATES (EXPERIMENT 2)

Fermentation time, h	Digestibility, %		
	DM	OM	NDF
24	27.1 ^c	26.2 ^c	22.0 ^c
48	46.2 ^b	43.7 ^b	34.2 ^b
SEM ^a	.7	.6	.6

^aStandard error of the mean.

^{b,c}Means in the same column with different superscript letters differ (P < .05).

EFFECT OF PRENATAL ANDROGENIZATION UPON PERFORMANCE AND CARCASS TRAITS OF HEIFERS USED IN A SINGLE CALVING HEIFER SYSTEM

B. A. Reiling, L. L. Berger, D. B. Faulkner, F. K. McKeith, and T. G. Nash

SUMMARY

The single calving heifer system has been shown to enhance efficiency of beef production, and prenatal androgenization (PA) has improved performance and carcass merit of feedlot heifers. This study compared the simultaneous feedlot production and lactational performance of control (C) and PA first-calf heifers. Three to 4 wks post-partum, 19 C and 16 PA heifer-calf pairs were placed in feedlot pens equipped with pinpointer feeding devices and fed an 85% concentrate, 13.5% CP diet. All calves were weaned at 112 days of age. Heifers were fed to a constant compositional endpoint of 1.1 cm s.c. fat cover, weighed, and processed at an average age of 855 d. Twenty-four h post-mortem, carcasses were evaluated for yield and quality traits. The completely randomized design was analyzed by the GLM procedure of SAS with variation due to breed of sire and calf sex removed. Data at weaning was adjusted to a constant compositional fat scan, and age of heifer was used as a covariant in analysis of carcass maturity and quality scores. Pre-weaning, PA heifers tended to gain faster ($P < .16$) and were 14.3% more efficient ($P < .03$). No differences were observed for lactational yield or composition. One carcass graded C-maturity and 71.4% graded choice.

INTRODUCTION

Traditional beef management systems involve two highly interrelated, yet physically separate phases of production. The cow-calf producer often strives to maximize longevity of the cow herd in an effort to reduce replacement costs of the reproductive unit per calf raised. However, maintenance of the mature, producing beef cow represents approximately 50% of total beef production costs and is relatively inefficient. The mature cow utilizes 70% of total metabolizable energy (ME) intake for maintenance (Ferrell and Jenkins, 1987), whereas the growing animal may use only 40% of ME intake for maintenance of lighter body weights. Taylor et al. (1985) also indicated that maximal efficiency of food utilization usually declines as the number of calvings per dam increases due to the cost of maternal overhead. Thus, the SCH system is designed to minimize the cost of retaining females by using the more efficient growing heifer which is bred to produce one calf followed by feedlot finishing and marketing of the heifer by approximately 30 months of age for the choice retail trade.

During the finishing phase, heifers tend to gain more slowly with less efficiency and produce carcasses of lower cutability than steers. However, PA has been used as an

effective method of enhancing growth performance and feed efficiency of heifers similar to that of steers. DeHaan et al. (1990) reported that PA feedlot heifers initially exposed to testosterone propionate (TP) in utero between d 40 and 80 of gestation gained 10.4% faster with 12.9% greater efficiency than control heifers. In addition, PA appears not to affect first conception fertility in the bovine and thus may be used synergistically with the SCH system.

MATERIALS AND METHODS

PA was accomplished by inserting four 15 cm TP implants subcutaneously posterior (behind) the scapula (shoulder) and over the rib cage on the left side of the pregnant cow. The TP implants, made of a medical-grade silastic tubing, contain approximately 2.25 g of crystalline TP and provide an average daily secretion rate of 37.8 mg TP (Kesler, 1987). Three weeks pre-partum, implants were removed from the cow. The PA heifer calves born to these implanted dams and a comparable set of controls were then reared as normal replacements and bred at approximately 15 months of age.

First-calf heifers used in the study calved at approximately 2 yr of age. Routine calving procedures were followed. Twenty-one to 28 d post-partum, groups of 6 heifer-calf pairs were individually weighed on each of two consecutive days and moved to drylot pens equipped with 4000B or "dummy" pinpointer feeding devices. Heifer-calf pairs were then rotated between the two types of feeders at 2-wk intervals. Individual feed intakes were recorded using the pinpointer feeding devices, while pen feed intakes were recorded from the "dummy" feeders during the 2-wk period. Individual feed intakes from "dummy" feeders were estimated by calculating the individual's percent intake of the total intake from the pinpointer feeders. This percentage was then used to calculate an approximate individual intake from the "dummy" feeders.

Heifers were fed a 13.5% crude protein (CP) diet formulated as shown in Tables 1 and 2 to meet or exceed NRC (1984) requirements for CP, Ca, P, K, trace minerals, and vitamins. Cattle were weighed every 28 d throughout the trial.

Milk production was measured at approximately 35, 70, and 105 d post-partum. The day prior to milking, calves were separated from dams at 1300 h (1 PM). At 1945 h (7:45 PM) calves were allowed to nurse until full (approximately 2000 h (8 PM)). This effectively removed all milk from the udder. Calves were again separated from their dam until after milking the next day. The following morning at 0800 h (8:00 am), heifers were given 5 cc (100 U.S.P. units) of oxytocin intramuscularly to stimulate milk letdown and milked by machine. Twelve h milk weights were multiplied by two to yield a 24-h production. A 28 g (1 oz) milk sample was collected and analyzed for fat and crude protein content by infrared analysis. An additional sample was collected and analyzed for solids non-fat by the procedure of Golding (1959).

At 112 d post-partum, heifers and calves were weighed on each of two consecutive

days and weaned. Heifers remained on feed until determined to possess 1.0 cm (.4 in) subcutaneous fat cover by a real-time linear array ultrasound instrument. Final termination weights were again taken on each of two consecutive days, and heifers processed at either a commercial packing plant or the University of Illinois Meats Laboratory. Twenty-four h postmortem, carcasses were evaluated for quality and yield grade traits by trained personnel.

RESULTS AND DISCUSSION

Economic success of the SCH system is dependent upon minimization of both dystocia problems and marketing of C-maturity (old or hard bone) carcasses. Since younger, heavier conditioned females tend to have greater calving difficulties, there is little that can be done to practically alter age of first calving. The heifers should be managed as normal replacements. However, post-partum, feedlot performance to achieve market readiness must be maximized. Thus, the lactating female and calf are placed in the feedlot where the heifer is fed a high energy, finishing diet (Table 1) to simultaneously support lactation and growth.

Pre-weaning performance of the heifers, calves, and pairs is shown in Table 3. Control and PA females similarly consumed approximately 14.5 kg/d (31.9 lbs/d) of dry matter. These lactating heifers consumed approximately 2.62% of their average body weight daily in comparison to a small number (5) of similarly aged, non-lactating females who consumed only 2.21%. Although not significant, lactating PA heifers gained 9.03% (1.69 vs. 1.55 kg/d) faster than lactating control heifers. Last year, we (Reiling et al., 1993) reported that lactating PA females under nearly identical management conditions gained .51 kg/d (1.1 lbs/d) faster than controls. However, the 9% improvement in average daily gain seems more realistic and corresponds well with the 10.4% improvement of daily gain of PA feedlot heifers reported by DeHaan et al. (1990). As with last year's study, PA heifers were 14.3% more efficient ($P < .03$). Gain to feed ratios of PA and control heifers were .120 (8.33 units of DM feed per unit of gain) and .105 (9.52 units of DM feed per unit of gain).

PA of the heifer had no impact upon calf performance (Table 3) or lactation (Table 4). Calves had an average birth weight of 35 kg (77 lbs) and weighed approximately 60 kg (132 lbs) 3 wks post-partum when placed in the feedlot with their dam. At 112 d of age, calves of control and PA heifers were weaned weighing 162 kg (358 lbs) and 152 kg (335 lbs), respectively. As reported by Brethour and Jaeger (1989), we also have observed the occurrence of cross-suckling within these confinement conditions, and weight gain of the calf may not be indicative of the dam's milk potential. Thus, to evaluate lactational performance, calves were separated from the dam for 6 h, allowed to nurse, re-separated, and dams milked by machine the following morning. Five wks post-partum, control and PA heifers yielded 8.88 and 9.01 kg (19.6 and 19.9 lbs) of 4% fat corrected milk (NRC, 1989) in a 24 h period, respectively, despite gaining more than 1.55 kg/d (3.42 lbs/d). Through weaning (112 d post-partum), control and PA 4%

fat corrected milk yields declined 1.39 kg/d (3.06 lbs/d) and 2.08 kg/d (4.58 lbs/d), respectively. At 5 wks, milk fat percent was approximately 3.2%, but declined to approximately 2% at 10 and 15 wks post-partum as a result of the high energy diet being fed.

Overall, control and PA pairs (Table 3) consumed 16.18 kg/d (35.7 lbs/d) and 15.56 kg/d (34.3 lbs/d), respectively, in support of maintenance, growth, and lactation. Due to a non-significant advantage in control daily calf gain, there was no difference in heifer-calf pair daily gains or pair gain to feed ratios.

In 1993, Reiling et al. reported that a majority of the British crossed heifers used in the SCH system had accumulated body fat during the pre-weaning trial and were nearly market ready at the time of weaning. However, this year's study revealed that the Simmental crossed control and PA heifers required an additional 46 and 33 d on feed post-weaning, respectively, to achieve 1 cm (.4 in) subcutaneous fat cover. Pre- and post-weaning (Table 6), PA heifers required 13 fewer days ($P < .02$) to achieve market readiness as a result of gaining .14 kg/d (.31 lbs/d) faster ($P < .09$). Again, this 10.9% enhancement of gain due to PA agrees with the findings of DeHaan et al. (1990).

Carcass traits of heifers are shown in Table 7. Due to greater visceral mass and udder weights, dressing percents (56.6%) are less than that of typical feedlot cattle. It is also evident that we were successful in marketing the two treatment types at equivalent fat thicknesses of 1.06 cm (.42 in). Other yield factors evaluated were also similar across treatment. Of most concern to the producer and consumer in using such a management system is that of quality. All heifers averaged 855 d of age at slaughter. Bone, lean, and overall maturity scores were also similar across treatment indicating that PA does not negatively alter physiological maturity as determined by subjective carcass indicators. Control carcasses did show a higher ($P < .02$) average marbling score than PA, but all heifers averaged above small⁰ (low choice). Also, based upon notations of the federal grader, 73.56 and 69.48% of the control and PA carcasses, respectively, graded choice. Only 1 carcass was classified as C-maturity.

IMPLICATIONS

Although results were not as favorable for PA as those reported in 1993, PA did improve daily gains and feed efficiency by approximately 10%, and should be economically beneficial to the producer. For the second consecutive year, however, we have shown that first-calf heifers can early wean (112 d) a healthy 160 kg (350 lb) calf under feedlot conditions, and be marketed as choice beef for the retail consumer. These management techniques offer potential for increased efficiency and profitability of smaller Midwest cattle producers who operate under retained ownership.

REFERENCES

- Brethour, J. R. and J. R. Jaeger. 1989. The single-calf heifer system. Kansas Agric. Sta. Rep. of Progress 570.
- DeHaan, K. C., L. L. Berger, D. J. Kesler, F. K. McKeith, D. B. Faulkner, G. F. Cmarik, and R. J. Favero. 1990. Effects of prenatal testosterone treatment and postnatal steroid implantation on growth performance and carcass traits of heifers and steers. J. Anim. Sci. 68:2198.
- Ferrell, C. L. and T. G. Jenkins. 1987. Influence of biological type on energy requirements. Proc. Grazing Livestock Nutrition Conference. Jackson, WY. pp 1-7.
- Golding, N. S. 1959. A solids-not-fat test for milk using density plastic beads as hydrometers. J. Dairy Sci. 42:899 (Abstr.).
- Kesler, D. J. 1987. Novel approaches and applications of steroid hormone delivery via polydimethylsiloxane. Proc. Am. Chem. Soc. Div. Poly. Mater. Sci. Eng. 57:408.
- NRC. 1984. Nutrient Requirements of Beef Cattle (6th Ed.). National Academy Press, Washington, DC.
- NRC. 1989. Nutrient Requirements of Dairy Cattle (6th Ed.). National Academy Press, Washington, DC.
- Reiling, B. A., L. L. Berger, D. B. Faulkner, F. K. McKeith, and T. G. Nash. 1993. Effect of prenatal androgenization upon performance, lactation, carcass, and sensory traits of heifers in a single calving heifer system. In: Beef Research Report 1993. pp 53 - 64. University of Illinois, Urbana.
- Taylor, C. S., A. J. Moore, R. B. Thiessen, and C. M. Bailey. 1985. Efficiency of food utilization in traditional and sex-controlled systems of beef production. Anim. Prod. 40:401.

TABLE 1. COMPOSITION OF DIETS FED^a

Ingredient	Days			
	1 - 5	6 - 10	11 - 15	> 15
Ammoniated corn cobs	45	35	25	15
Corn, whole	40	50	60	70
Corn distillers solubles	5	5	5	5
Pelleted Supplement	10	10	10	10

^aPercent of diet (DM basis)

TABLE 2. COMPOSITION OF SUPPLEMENT

Ingredient	% as-fed	DM parts
Soybean meal	68.70	61.14
Blood meal	3.20	2.98
Dry molasses	2.58	2.43
Urea	7.42	7.42
Rumensin	.20	.20
Limestone	10.00	10.00
Dicalcium phosphate	2.50	2.50
TM salt + Se	3.50	3.50
Zn Chelate	.10	.10
Vitamin ADE	.15	.15
Thiamin premix	.15	.15
Potassium chloride	1.50	1.50
Total	100.00	92.064

TABLE 3. EFFECT OF PRENATAL ANDROGENIZATION (PA) UPON PRE-WEANING PERFORMANCE OF HEIFERS AND THEIR CALVES IN A SINGLE CALVING HEIFER SYSTEM

Item	Control	PA	SEM ^a	Treatment Effect ^b
No. of animals	19	16		
Days on test, pre-weaning	88	88	1	.66
Heifer on-test wt, kg	496.4	472.6	11.0	.14
Heifer off-test wt, kg	632.6	620.1	12.6	.49
Heifer dry matter intake, kg/d	14.78	14.13	.41	.28
Heifer dry matter intake, % of BW	2.65	2.60	.08	.69
Heifer daily gain, kg/d	1.55	1.69	.07	.16
Heifer gain/feed ratio	.105	.120	.005	.03
Calf birth wt, kg	35.6	34.2	1.1	.34
Calf on-test wt, kg	60.7	58.7	1.7	.41
Calf off-test wt, kg	162.3	152.1	5.1	.18
Age of calf @ weaning, d	112	113	1	.40
Calf dry matter intake, kg/d	1.40	1.43	.07	.74
Calf daily gain, kg/d	1.15	1.07	.05	.23
Pair ^c dry matter intake, kg/d	16.18	15.56	.40	.29
Pair ^c daily gain, kg/d	2.71	2.76	.07	.62
Pair ^c gain/feed ratio	.168	.178	.005	.16

^aGreatest standard error of treatment means (SEM) reported.

^bProbability of observing a greater F-value.

^cPerformance of heifer and calf combined for the pre-weaning period.

TABLE 4. EFFECT OF PRENATAL ANDROGENIZATION (PA) UPON MILK PRODUCTION AND COMPOSITION SAMPLED AT 5, 10, AND 15 WEEKS POST-PARTUM

Item	Control	PA	SEMa	Treatment Effect ^b
No. of animals	19	16		
Age of calf @ weaning, d	112	113	1	.40
Calf weaning wt, kg	162.3	152.1	5.1	.18
5-wk post-partum milking				
24 h actual yield, kg	10.33	10.02	.74	.76
24 h 4% FCM ^c yield, kg	8.88	9.01	.73	.90
Fat, %	3.12	3.29	.26	.63
Protein, %	3.47	3.44	.05	.59
Solids non-fat, %	8.71	8.79	.11	.60
10-wk post-partum milking				
24 h actual yield, kg	11.92	10.90	1.01	.46
24 h 4% FCM ^c yield, kg	8.03	7.78	.78	.82
Fat, %	1.87	1.94	.16	.75
Protein, %	3.73	3.69	.06	.67
Solids non-fat, %	9.14	8.77	.06	.01
15-wk post-partum milking				
24 h actual yield, kg	10.61	9.67	.74	.36
24 h 4% FCM ^c yield, kg	7.49	6.93	.59	.49
Fat, %	2.07	2.06	.19	.97
Protein, %	3.91	4.01	.07	.24
Solids non-fat, %	9.07	8.84	.13	.21

^aGreatest standard error of treatment means (SEM) reported.

^bProbability of observing a greater F-value.

^c4% fat corrected milk (NRC, 1989)

TABLE 5. EFFECT OF PRENATAL ANDROGENIZATION (PA) UPON THE POST-WEANING FEEDLOT PERFORMANCE OF HEIFERS IN A SINGLE CALVING HEIFER SYSTEM

Item	Control	PA	SEM ^a	Treatment Effect ^b
No. of animals	19	16		
Days on feed post-weaning	46	33	4	.02
Feedlot dry matter intake, kg/d	11.00	11.52	.42	.37
Feedlot dry matter intake, % of BW	1.74	1.81	.06	.45
Feedlot daily gain, kg/d	.54	.79	.22	.40
feedlot gain/feed ratio	.052	.066	.018	.55

^aGreatest standard error of treatment means (SEM) reported.

^bProbability of observing a greater F-value.

TABLE 6. EFFECT OF PRENATAL ANDROGENIZATION (PA) UPON THE OVERALL PERFORMANCE TRAITS OF HEIFERS PRE- AND POST-WEANING

Item	Control	PA	SEM ^a	Treatment Effect ^b
No. of animals	19	16		
Total days on feed	134	121	4	.02
Overall dry matter intake, kg/d	11.39	11.65	.44	.67
Overall dry matter intake, % of BW	2.02	2.06	.08	.69
Overall daily gain, kg/d	1.28	1.42	.06	.09
Overall gain/feed ratio	.114	.125	.006	.22

^aGreatest standard error of treatment means (SEM) reported.

^bProbability of observing a greater F-value.

TABLE 7. EFFECT OF PRENATAL ANDROGENIZATION (PA) UPON CARCASS MERIT OF HEIFERS USED IN A SINGLE CALVING HEIFER SYSTEM

Item	Control	PA	SEMa	Treatment Effect ^b
No. of animals	19	16		
Live wt, kg	654.3	651.0	13.5	.87
Hot carcass wt, kg	369.8	369.2	8.0	.96
Dressing percent	56.54	56.72	.39	.75
Fat thickness, cm	1.06	1.06	.06	.99
Ribeye area cm ²	83.92	87.15	2.44	.34
% kidney, pelvic, and heart fat	2.62	2.46	.14	.40
Yield grade ^c	3.00	2.81	.15	.35
Heifer age at slaughter, d	855	855	7	.93
Bone maturity	195	194	12	.95
Lean maturity	172	178	8	.57
Overall maturity	183	186	9	.85
Marbling score	1096	1016	22	.02
% Choice	73.56	69.48	12.13	.81

^aGreatest standard error of treatment means (SEM) reported.

^bProbability of observing a greater F-value.

FAT TREATED HAY TO DECREASE STORAGE LOSS AND IMPROVE ANIMAL PERFORMANCE

J. W. Castree, D.B. Faulkner and D. D. Buskirk

SUMMARY

Ninety (90) Angus-Simmental crossbred heifers (612.4 lb) were utilized in three blocks to evaluate four hay treatments on nutrient recovery and animal performance. The four hay treatments were stored outside-no treatment, shed stored-no treatment, stored outside-tarp covered and store outside-fat treated (2 lb/cwt of hay). Throughout the trial (56 days) heifers had ad libitum access to large round bales (weighed and sampled at time of storage treatment and prior to feeding) and were supplemented with 3 lbs of cracked corn/head/day. Nutrient recovery over time (224 d) at three levels of fat treatment (1, 2, and 3 lbs/cwt of hay) also were examined. Hay intake was not influenced ($P > .53$) by treatment. Feed efficiency ($P > .79$) and average daily gain ($P > .45$) were not significantly affected by treatment. Gain to feed ratios were .074, .094, .082 and .087 for no treatment, shed stored, tarp covered and fat treated hay, respectively. Average daily gains were, 1.24, 1.64, 1.52 and 1.51 lb/d, for the same treatments. Percentage dry matter loss and hay refusal were lowest for shed stored hay, 9.4% and 1.9% respectively. Hay stored outside-no treatment had the greatest storage loss (11.4%) while tarp covered hay refusal was greatest (6.7%). There were no differences in nutrient recovery between the three levels of fat treatment.

INTRODUCTION

Large round bales of hay have become the predominate harvested feed for wintering beef cows in west-central Illinois. Many beef producers prefer this method of hay harvest because of reduced labor requirements when the hay is baled and at feeding. Spoilage occurs when hay is stored outside. Estimated dry matter losses resulting from outdoor storage may total 15-20% higher than bales stored indoors. Factors influencing bale quality include type of forage, bale density, length of storage and amount of precipitation during storage. Producers can influence the amount of forage waste and nutrient loss by the method in which round bales are stored. An effective, low cost, easily implemented method of round bale storage should be an integral part of each beef producers feed resource management. The objectives of this trial were to evaluate four methods of round bale storage (stored outside-no treatment, shed stored-no treatment, stored outside-tarp covered and stored outside-fat treated) on nutrient recovery and animal performance. An additional objective was to evaluate three levels of fat treatment on nutrient recovery.

PROCEDURE

Ninety Angus-Simmental crossbred heifers (612.4 lb) were utilized in three blocks to evaluate four hay treatments (12 pens total) on nutrient recovery and animal performance. Initial weights (seven days after weaning) and final weights were recorded following a 16h removal from feed and water. Heifers were supplemented with 3 lb of cracked corn/head/day and had ad libitum access to large round bales throughout the trial (56 days). Prior to bale feeding, hay refusal from the previous bale was removed, weighed and sampled to determine dry matter. Heifers were maintained in drylot (7-9 animals/pen) and had access to open front sheds. No bedding was used during the trial.

The four hay treatments were stored outside-no treatment (NT), shed stored-no treatment (SS), stored outside-tarp covered (TC) and stored outside-fat treated (FT). Third cutting alfalfa hay was purchased locally from one producer and was weighed and sampled upon delivery. Individual bales ($n=56$) were weighed to the nearest 10 lb on a certified scale and randomly assigned to treatment ($n=14$). A core sample (12.0 x 0.75 in) was taken from each bale at time of delivery and when fed. Composite samples by treatment and within two week intervals during feeding were analyzed for moisture, CP, ADF and NDF by a commercial feed testing lab. Bales of hay stored outside were placed on a 4-6 inch layer of coarse 2 inch crushed rock. The bale storage area had adequate slope to provide good drainage of surface water. Bales stored outside were placed end-to-end in a north-south direction. SS hay was stored in a 40 x 80 ft open front shed. TC hay was stacked in a 3-2-1 pyramid configuration and covered with a woven polyethylene fabric. FT hay received 2 lb/cwt of hay of melted food-grade hydrogenated beef tallow. Precipitation during the trial totalled 16.82 inches. The data were analyzed using a general linear model with type of bale treatment and block as main effects.

Three levels of fat treatment (1, 2, and 3 lbs/cwt of hay), untreated, shed stored and tarp covered bales were examined, utilizing two bales per treatment level. Fat treated bales were stored outside and treated with melted food-grade hydrogenated beef tallow. Core samples (12.0 x 0.75 in) were taken from all bales at the time of fat treatment, 115 and 224 days following treatment. Samples were analyzed for moisture, CP, ADF and NDF by a commercial feed testing lab. Cumulative precipitation during this period (224 d) was 24.75 inches. The data were analyzed using a general linear model with bale treatment and time of sampling as main effects.

RESULTS

The effects of hay storage on heifer performance are reported in Table 1. Average daily gains were similar for all treatments. Daily gains of heifers fed SS hay tended to be greater (24.4%) than heifers fed NT hay (1.64 vs 1.24 lb/day, $P=.18$). Dry matter intake was not different among treatments ($P>.53$). Feed efficiency was similar for all treatments.

Hay samples taken at time of feeding were not significantly different in CP, ADF or NDF. Storage and feeding losses of hay were not significantly influenced by method of bale storage (Table 2). TC hay refusal was greatest (6.7%) and tended to be higher than SS hay ($P = .06$). Heat damage of TC hay in the interior of the stack may have contributed to these results.

TABLE 1. EFFECT OF HAY STORAGE ON HEIFER PERFORMANCE

Item	Treatment				SE
	Control	Shed	Tarp	Fat	
Gain, lb/d	1.24	1.64	1.52	1.51	.18
Hay Intake, lb/d	14.2	14.8	15.9	14.9	.83
Corn intake, lb/d	2.7	2.7	2.7	2.7	
Gain/feed	.074	.094	.082	.087	.013

No significant differences in CP or ADF were observed among the different levels of fat treatment, shed stored, tarp covered or untreated bales during the 224 d storage period. However, percent dry matter loss ($P < .01$) and NDF ($P < .01$) were affected by method of storage. Shed stored bales had the lowest dry matter loss (5%). The three levels of fat treatment, (1, 2, and 3 lbs/cwt of hay) had dry matter losses of 20.6%, 20.3% and 17% respectively. Tarp covered and untreated bales each had a dry matter loss of 21.5% during the storage period. In addition, ADF and NDF values increased during storage by 15% and 19% respectively for hay stored outside. Shed stored hay increased 3% and 11% for ADF and NDF respectively.

TABLE 2. EFFECT OF HAY STORAGE ON FEEDING AND STORAGE LOSS

Item	Treatment				SE
	Control	Shed	Tarp	Fat	
Storage loss, %	11.4	9.4	9.9	11.0	
Refusal, %	4.9	1.9	6.7	6.2	1.7
Total	16.3	11.3	16.6	17.2	

CONCLUSIONS

Shed storage of hay resulted in the best heifer performance and least feeding and storage loss. Shed stored hay had 31% less storage and feeding losses than untreated hay when stored for 224 days and receiving 24.75 inches of precipitation. As length of storage and amount of precipitation increased the advantage of shed storage in reducing dry matter loss increased.

Hay quality was not influenced by method of storage. Increasing length of storage will increase ADF and NDF values. Therefore potential animal intake and digestibility of the hay will decline. Dry matter losses of 21% can be expected to occur on bales stored outside. These losses must be taken into consideration when determining the amount of hay required for winter feeding.

FACTORS INFLUENCING FREEZE BRANDING SUCCESS OF ANGUS AND ANGUS X HEREFORD CROSSBRED HEIFERS

F. A. Ireland, D. D. Buskirk and D. B. Faulkner

SUMMARY

Three hundred ninety-four Angus and Angus x Polled Hereford crossbred heifers ranging in age from 8 to 18 months were freeze branded using dry ice and alcohol in one of three trials. The objectives of these studies were to evaluate the effects of breed, age, length of time, and technician on freeze branding success. In trials 1 and 2 involving weanling and yearling heifers respectively, crossbred heifers had fewer brands scored as under branded and a higher percentage of legible brands. In trial 3, breed x time interactions were linear ($P = .03$) and quadratic ($P = .03$). Technician was also a significant source of variation ($P < .03$) in trial 3.

INTRODUCTION

Freeze branding of farm animals has been in use since the 1960's (Smithson *et al.*, 1970), however, its acceptance as a means of permanent identification has been affected by the poor results of many producers. When properly applied, freeze brands destroy the pigment producing portion of the hair follicle resulting in white hair growth which is highly visible at a distance. In addition, freeze brands appear to be relatively painless and do not damage the hide of the animal.

Methods of freeze branding farm animals have been published in extension and veterinarian reports in recent years (Ross and Massey, 1966; Smithson *et al.*, 1970; Farrell, 1979) with a wide range of techniques and results. The objectives of these studies were to evaluate the effects of breed, age, length of time and technician on freeze branding results using dry ice and alcohol as coolants on Angus and Angus x Polled Hereford crossbred heifers.

MATERIALS AND METHODS

Three hundred ninety-four Angus and Angus x Polled Hereford heifers ranging in age from 8 to 18 months were utilized in one of three trials. The following procedures was used on all experimental animals. A slurry of dry ice and methyl alcohol was prepared in a styrofoam cooler by adding chunks of dry ice to methyl alcohol of sufficient quantity to extend approximately one inch above the freeze branding digit. The branding irons were allowed to remain in the liquid until the vigorous bubbling ceased, indicating the irons had reached the temperature of the liquid. The branding irons were four-inch numerals and letters manufactured by L & H Manufacturing and purchased through Nasco, Fort Atkinson, Wisconsin. The animals were restrained in a livestock chute and the left hip of the animal was clipped using a large animal clipper (Oster®, Model 150) and surgical blades to allow sufficient space to apply four in-line digits. Dirt and debris were removed by brushing and the area was sprayed with

methyl alcohol immediately prior to applying each iron. Age, breed, time of application and technician were recorded for each animal. All animals were branded in November and December of 1992 at the Dixon Springs Agricultural Center, University of Illinois.

All brands were evaluated after the animals' hair had changed color the next spring. Each brand was evaluated without clipping and placed in one of four categories: over branded, under branded, marginally satisfactory, and satisfactory. For the purpose of evaluation, the marginally satisfactory and satisfactory categories were combined to form a category labeled legible.

Eighty-six Angus and Angus x Polled Hereford weanling heifers (\approx 8 to 11 months of age) were utilized in trial 1. Branding times ranged from 40 to 60 seconds at 5-second increments. In trial 2, 41 yearling heifers (\approx 18 months of age) were branded at a time of either 45 or 50 seconds. Trial 3 involved 267 yearling heifers (\approx 18 months of age) branded at times ranging from 40 to 60 seconds at 5-second increments.

Variables were evaluated statistically by analysis of variance with the GLM procedure of SAS (1982). The model statement contained over, satisfactory, marginal, under and legible as dependent variables. Technician, breed, time iron was applied, and breed x time interaction were independent variables. Time iron was applied was analyzed using linear and quadratic contrasts.

RESULTS AND DISCUSSION

In trial 1, there was a significant effect of breed on freeze branding results. Angus x Polled Hereford crossbred weaning heifers had fewer brands scored as "under" branded than did Angus weanling heifers (21.2 vs 44.4, $P < .02$) (Table 1). This resulted in more brands being scored "legible" for crossbred heifers (78.8 vs 55.6; $P < .02$) (Table 1). There was no significant difference of time or technician in trial 1. Trial 2 showed similar results with crossbred Angus x Polled Hereford yearling heifers having fewer under branded brands (23.7 vs 58.6, $P < .01$), more marginally satisfactory (56.4 vs 22.8, $P < .001$) and more brands being legible (75.5 vs 40.1, $P < .01$) than did the straight Angus heifers (Table 2).

Technician was a significant source of variation in trial 3 for legible ($P = .03$) and under branded ($P = .02$) categories. Technician was, therefore, removed as an independent variable and included as a covariant for the remaining analysis. Breed x time interactions in trial 3 were linear ($P = .03$) for "marginal" brands and quadratic ($P = .03$) for "under" brands (Table 3). These results are difficult to explain and probably are not biologically significant. Numerically, yearling crossbred heifers had more legible brands than did straight-bred yearling Angus heifers.

CONCLUSIONS

The results of these three trials indicate that there is little difference between branding times from 40 and 60 seconds on weanling or yearling heifers when using dry ice and alcohol. No increase in the number of brands "over" branded as time increased suggests that either 60 seconds was not a long enough period of time or that perhaps the irons were warming up during this range of times such that over branding did not occur. These trials also suggest that results of branding crossbred heifers may be more legible than brands on straight Angus heifers of the same age.

Freeze branding has great potential as a method of permanent identification for livestock producers. Further research is needed to identify factors influencing success of freeze branding. With improved techniques, producers will have increased confidence in freeze branding as a reliable means of livestock identification.

REFERENCES

- Farrell, R. K. 1979. A universal system for positive, unalterable identification of horses. *Norden News*, pp. 14-18.
- Ross, J. E. and J. W. Massey. 1966. Freeze branding cattle. *MU Guide* 12/66 7M:2201-2202. University of Missouri, Columbia, MO.
- SAS. 1982 SAS user's guide: Statistics. SAS Inst. Inc., Cary, NC.
- Smithson, L. J., H. W. Essig, C. B. Shawver, L. H. Boyd and B. Baker, Jr. 1970. Freeze branding of beef cattle, horses and swine. Information Sheet 1095, Mississippi State University.

Table 1. Freeze Branding Results of Weanling Heifers (Trial 1)*

Brand score	Breed		P =
	Ang	Ang x Here	
Over, %	0	0	0
Satisfactory, %	34.3 ± 9.6	47.1 ± 5.0	.25
Marginal, %	21.3 ± 7.0	31.7 ± 3.7	.20
Under, %	44.4 ± 8.5	21.2 ± 4.5	.02
Legible, %	55.6 ± 8.5	78.8 ± 4.5	.02

Brand score	Time, seconds				
	40	45	50	55	60
Over, %	0	0	0	0	0
Satisfactory, %	36.2 ± 11.8	33.2 ± 9.0	37.2 ± 10.1	46.9 ± 10.5	50.0 ± 10.4
Marginal, %	21.0 ± 8.7	31.9 ± 6.7	38.7 ± 7.4	21.8 ± 7.7	19.4 ± 7.7
Under, %	42.9 ± 10.5	35.0 ± 8.0	24.1 ± 8.9	31.4 ± 9.3	30.6 ± 9.2
Legible, %	57.1 ± 10.5	65.0 ± 8.0	75.9 ± 8.9	68.6 ± 9.3	69.4 ± 9.2

*LS Means ± SE

Table 2. Freeze Branding Results of Yearling Heifers (Trial 2)*

Brand score	Breed		P =
	Ang	Ang x Here	
Over, %	2.2 ± 1.0	.8 ± 1.5	.43
Satisfactory, %	17.3 ± 6.0	19.0 ± 8.5	.87
Marginal, %	22.8 ± 5.4	56.4 ± 7.7	.001
Under, %	58.6 ± 7.7	23.7 ± 10.9	.01
Legible, %	40.1 ± 7.5	75.5 ± 10.7	.01

Brand score	Time, seconds		P =
	45	50	
Over, %	3.4 ± 1.4	0 ± 1.1	.04
Satisfactory, %	16.7 ± 8.6	19.6 ± 6.3	.78
Marginal, %	37.9 ± 7.8	41.3 ± 5.7	.72
Under, %	41.9 ± 11.0	39.4 ± 8.0	.86
Legible, %	54.6 ± 10.8	61.0 ± 7.9	.64

*LS Means ± SE

Table 3. Freeze Branding Results of Yearling Heifers (Trial 3)^a

Brand Score	Time, seconds				
	40	45	50	55	60
Angus					
Over, %	.1 ± 4.2	2.1 ± 1.7	8.6 ± 2.7	0 ± 4.8	0 ± 6.0
Satisfactory, %	30.5 ± 10.8	43.3 ± 4.4	46.2 ± 6.7	19.0 ± 12.1	41.6 ± 15.1
Marginal ^b , %	40.1 ± 8.3	25.6 ± 3.4	30.4 ± 5.2	20.8 ± 9.3	30.5 ± 11.6
Under ^c , %	29.3 ± 9.4	29.0 ± 3.8	14.8 ± 5.8	60.3 ± 10.5	28.0 ± 13.1
Legible, %	70.6 ± 9.8	68.8 ± 4.0	76.7 ± 6.1	39.8 ± 11.0	72.1 ± 13.7
Angus x Hereford					
Over, %	0 ± 4.4	6.0 ± 2.3	8.4 ± 2.7	5.5 ± 3.7	9.3 ± 5.6
Satisfactory, %	61.0 ± 11.1	46.6 ± 6.0	30.0 ± 7.0	38.8 ± 9.5	54.4 ± 14.2
Marginal ^b , %	26.2 ± 8.5	30.0 ± 4.6	39.2 ± 5.3	38.2 ± 7.3	16.3 ± 10.9
Under ^c , %	12.8 ± 9.6	17.4 ± 5.2	22.4 ± 6.0	17.6 ± 8.3	20.0 ± 12.3
Legible, %	87.3 ± 10.1	76.6 ± 5.4	69.2 ± 6.3	77.0 ± 8.6	70.8 ± 12.9

^aLS Means ± SE

^bBreed x Time interaction (P = .03)

^cBreed x Time quadratic effect (P = .03)

DETERMINATION OF PREGNANCY IN BEEF COWS SUBMITTED TO PROGESTOGEN THERAPY FIVE DAYS AFTER BREEDING

R. Machado and D.J. Kesler

SUMMARY

Administration of norgestomet implants in beef cows on day 5 and left in situ until day 21 after breeding allowed substantial improvements in determination of pregnancy by serum progesterone determination.

INTRODUCTION

Precocious diagnosis of pregnancy is an important tool of management in beef cattle operations. In addition, re-synchronization protocols require an accurate diagnosis of pregnancy prior to the second timed-artificial insemination (AI) not only to prevent the detrimental effects of mating females already pregnant but also to correctly determine the highest possible number of open females to be destined to a second service.

This study aimed to find the ideal cut-off serum progesterone concentration that provides the highest accuracy of pregnancy determination associated with the highest negative predictive value of the assay.

PROCEDURES

Fifty-eight postpartum beef cows were synchronized by means of an intramuscular injection of norgestomet (3.0 mg) and valerate estradiol (5.0 mg) in a sesame oil and benzyl alcohol (10%). At the same time a silicone implant containing 6.0 mg of norgestomet was subcutaneously inserted into the convex surface of the ear. The implant was removed 9 days after its insertion and the cows were artificially inseminated approximately 48 hours after implant withdrawal (Syncro-Mate B). On day 5 after the artificial insemination cows received either a 6 mg or a 8 mg norgestomet silicone implant, which was subcutaneously inserted into the ear and remained in situ for 16 days. Serum samples were obtained at the same time of implants removal progesterone concentration was determined in the serum through a validated enzyme immunoabsorbant assay (ELISA; Kesler et al., 1990).

Concentration of 1.5 ng/ml or above at the time of explanation was considered as the standard to indicate pregnancy to the first timed-artificial insemination (Favero et al., 1993). In addition, various progesterone cut-off points were hypothetically assessed and accuracy, sensitivity, specificity, and positive and negative predictive values were determined. Calvings placed on 283 ± 11 days from the date of the artificial insemination were considered to determine calving rates and compute the parameters mentioned

previously.

Student's t test was employed to compare the means of progesterone concentration between correct and erroneous diagnoses of pregnancy. All analysis were run using the SAS program (SAS user's guide, 1985).

RESULTS

The accuracy of progesterone concentration measurements to predict pregnancy and determine cows to be bred at a second synchronized service is compiled in the Table 1.

Accuracy in determining pregnancy status based on the standard serum progesterone concentration (≥ 1.5 ng/ml) on day 21 after initial AI was 88.1% (Table 1).

Cows accurately determined as pregnant showed a significantly higher ($P < .05$) serum concentrations of progesterone (9.53 ± 1.83 ng/ml) 21 days after breeding than cows considered pregnant and that failed to calve to the initial artificial insemination (6.02 ± 4.16 ng/ml). Moreover, the lowest concentration of progesterone observed for accurately determined pregnant cows ($n=15$) was 7.17 ng/ml, in contrast to four cows erroneously taken as pregnant and that had concentrations lower than 4.00 ng/ml.

Table 2 shows the hypothetical increase in serum progesterone cut-off points and their effect on several parameters related to pregnancy diagnosis in cows.

DISCUSSION

It could be verified that as cut-off increased up to 4.0 ng/ml, the specificity, accuracy and positive predictive value of the assay also increased. As a result, fewer false positive diagnosis would be made and no increase in the number of false-negatives would happen. Improvements in these parameters affect the number of cows destined to be re-inseminated after the removal of the second implant and consequently increase the likelihood of obtaining a higher combined calving rate to the two first breedings. In addition, cows with progesterone levels ranging from 1.5 to 4.0 ng/ml might be destined to a second AI based on estrus observation for a short period of time after removal of the second implant.

CONCLUSIONS

The overall accuracy of serum progesterone analysis to define which cows were to be re-bred was 87.9%. It is possible that the cutoff point employed should be elevated to enhance the number of correct diagnoses. This should increase the number of cows destined to be re-inseminated and the likelihood of a higher pregnancy rate to a

second artificial insemination.

REFERENCES

- Favero, R.J, D.B. Faulkner and D.J. Kesler. 1993. Norgestomet implants synchronize estrus and enhance fertility in beef heifers subsequent to a timed artificial insemination. J. Anim. Sci. 71:2594-2600.
- Kesler, D.J., H. Khazali and R.J. Favero. 1990. Quantification of steroids via a polymer linked second antibody immunoassay: methods of linking anti-rabbit IgG to poly(styrene). In: Progress in Biochemical Polymers. Ed., C.G. Gebelin and R. Dunn. Plenum publishing co., New York, NY.
- SAS User's guide: Statistics. SAS Institute Inc., Cary, 1985.

TABLE - 1. ACCURACY¹ OF SERUM PROGESTERONE ANALYSIS² TO DETERMINE THE NUMBER OF COWS TO BE RE-INSEMINATE AFTER SYNCHRONIZATION WITH SYNCRO-MATE B ASSOCIATED OR NOT WITH PGF_{2α} PRE- TREATMENT AND SUBMITTED TO RE-SYNCHRONIZATION WITH NORGESTOMET IMPLANT³.

P ₄ level ⁴	Diagnosis ⁵				Accuracy (%) ⁶		
	Pregnant		Open		No PGF _{2α}	PGF _{2α}	Combined
	No PGF _{2α}	PGF _{2α}	No PGF _{2α}	PGF _{2α}			
High	09	06	02	05	81.8 (9/11)	54.5 (6/11)	68.2 (15/22)
Low	0	0	17	19	100.0 (17/17)	100.0 (19/19)	100.0 (36/36)
Overall					92.8 (26/28)	83.3 (25/30)	87.9 (51/58)

¹ Relation between number of correct diagnoses and total number of diagnoses made.

² Serum determination through a validated ELISA.

³ All cows were submitted to the traditional SMB program associated or not with a 25 mg PGF_{2α} injection five days before implant insertion. The second norgestomet implant was administered on the fifth day subsequent to the initial breeding and maintained in situ for 16 days.

⁴ High level was considered to be concentrations of ≥ 1.5 ng/ml and low level was concentrations of < 1.5 ng/ml.

⁵ Cows with high level of P₄ at removal of the 2nd implant were considered pregnant to the initial artificial insemination (on the day 21 since breeding).

⁶ Number of animals is in parentheses.

TABLE - 2. EFFECT OF VARYING SERUM PROGESTERONE CONCENTRATION CUT-OFF POINTS ON ACCURACY, SENSITIVITY, SPECIFICITY, POSITIVE PREDICTIVE VALUE, AND NEGATIVE PREDICTIVE VALUE OF DAY 21 SERUM PROGESTERONE CONCENTRATIONS IN ESTIMATING PREGNANCY STATUS OF SYNCHRONIZED BEEF COWS.

P ₄ Cutoff (ng/ml) ¹	Sensitivity ²	Specificity ³	Accuracy ⁴	Predictive Value	
				Pos ⁵	Neg ⁶
1.0	100.0%	79.1%	86.4%	65.2%	100.0%
1.5	100.0%	81.4%	87.9%	68.2%	100.0%
2.0	100.0%	83.7%	91.4%	75.0%	100.0%
2.5	100.0%	88.4%	91.4%	75.0%	100.0%
3.0	100.0%	88.4%	91.4%	75.0%	100.0%
3.5	100.0%	88.4%	93.1%	78.9%	100.0%
4.0	100.0%	90.7%	94.8%	83.3%	100.0%
No data from 4.5 to 7.0 ng/ml					
7.5	86.7%	93.0%	91.4%	81.2%	95.3%
8.0	66.7%	93.0%	87.9%	78.6%	91.1%

¹ Females with day 21 serum progesterone concentrations ([P₄]) less than this level were classified as non pregnant and females with day 21 serum progesterone concentrations greater than this level were considered pregnant.

² Number of pregnant females having [P₄] greater than the cutoff point divided by the total number of pregnant females.

³ Number of non-pregnant females having [P₄] less than the cutoff point divided by the total number of non-pregnant females.

⁴ The proportion of all test results, both pregnant and non-pregnant, that were correct.

⁵ Number of pregnant females divided by the total number of females with [P₄] greater than the cutoff level (1 - false positives).

⁶ The proportion of females that indicated non-pregnancy, that were non-pregnant (1 - false negatives).

REPRODUCTIVE CONTROL IN BEEF COWS BY MEANS OF RE-SYNCHRONIZATION OF ESTRUS WITH NORGESTOMET

R.Machado and D.J. Kesler

SUMMARY

Silicone implants manufactured with either 6 or 8 mg of norgestomet were inserted on day 5 after a Syncro-Mate B (SMB) timed AI and left in situ until day 21. No detrimental effect on the calving rate to the SMB artificial insemination was observed. In addition, a second timed-artificial insemination was permitted on the non-pregnant cows with an overall calving rate was 57.1%. Both implants were effective if they continued to suppress estrus.

INTRODUCTION

One goal of controlling the estrous cycle and ovulation in beef cattle is to reduce the labor involved in estrus detection and artificial insemination (AI). However, when timed-AI is employed, pregnancy rates tend to be low and the wide spread use of superior genetics is limited. A second opportunity for a timed-AI reduces labor, synchronizes the return to estrus of non-pregnant females (Favero et al., 1993), and increases the number of calves born from AI.

The purpose of this study was to compare the effects of norgestomet impregnated silicone implants, which were inserted five days after the initial artificial insemination and left in situ for 16 days on the calving rate to a second timed-AI in postpartum beef cows.

PROCEDURE

Fifty-six cows received an injection of 3 mg norgestomet and 5 mg estradiol valerate associated with the subcutaneous insertion of a 6 mg norgestomet implant in the ear (Syncro-Mate B). Twenty-eight cows had been injected with 25 mg of PGF_{2α} five days prior to the synchronizing treatment. The implant remained in situ for 9 days and cows were artificially inseminated 48 after implant removal. An additional 6 mg or a 8 mg norgestomet silicone implant was given respectively to 28 and 28 cows five days after service. Implants were withdrawn 16 days later and a second artificial insemination was performed 48 hours after implant removal only in cows with low serum progesterone (<1.5 ng/ml) at implant removal. Progesterone concentration was determined through a validated enzyme linked immunoabsorbant assay (ELISA; Kesler et al., 1990). Calving rates according to implant used were determined based on the number of cows that calved in the interval of 283 ± 11 days from the date of the second AI. Differences in calving rate among treatment groups were determined through analysis of variance with pretreatment with PGF_{2α} and type of implant at re-synchronization as main effects.

DISCUSSION

None of cows displaying estrus while implant (6 mg) was in situ became pregnant to the second artificial insemination. As long as cows were kept out of estrus with 6 mg norgestomet implants the fertility was comparable [$7/(16-3) = 53.8\%$] to that observed for cows implanted with 8 mg cylinders ($10/19 = 52.6\%$).

The combined (6 mg and 8 mg implants) calving response to re-synchronization would have become 53.1% [$10+7/(16+19-3)$] for cows which estrus was efficiently suppressed after the first service. Such an occurrence might have been caused by a more tight synchrony between LH surge, ovulation subsequent to implant removal and the time of the second artificial insemination.

CONCLUSIONS

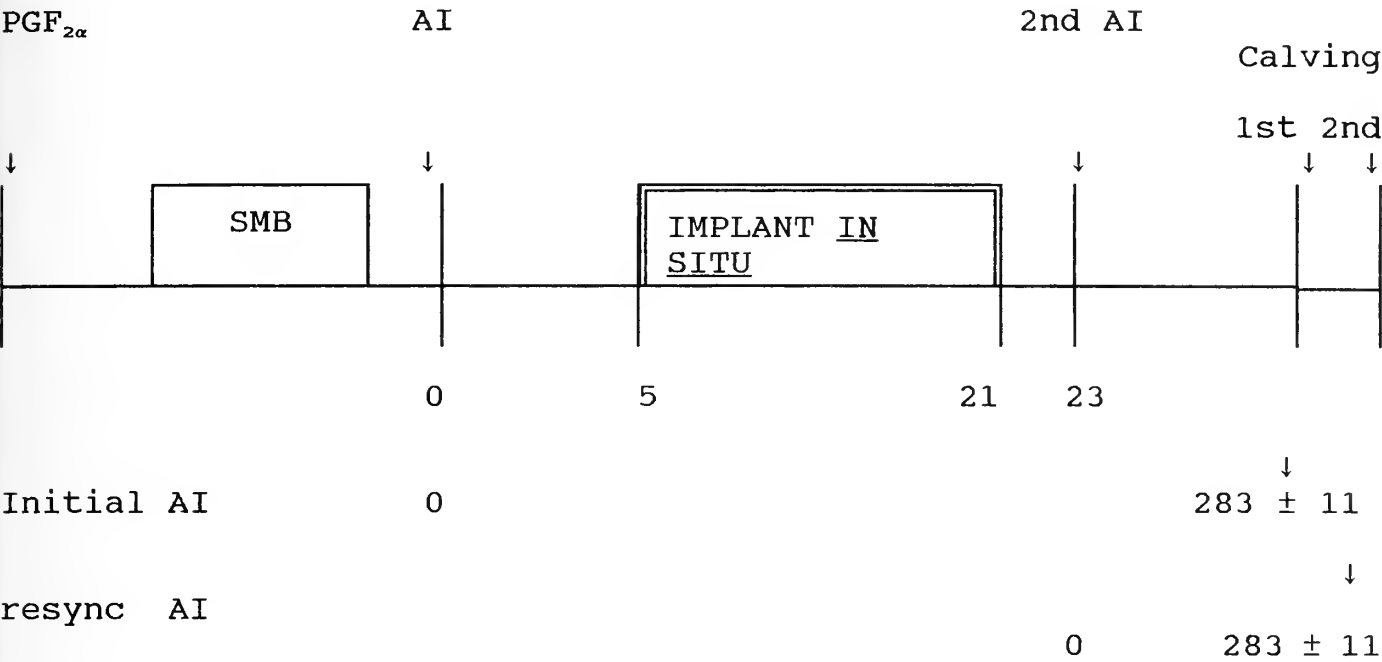
The use of norgestomet/silicone implants inserted 5 days after an initial breeding did not have negative effects on previous AI and re-synchronization protocols herein described effectively permitted the use of timed-breeding in two distinct occasions and resulted in a higher number of cows calving to AI.

REFERENCES

- Favero, R.J., D.B. Faulkner and D.J. Kesler. 1993. Norgestomet implants synchronize estrus and enhance fertility in beef heifers subsequent to a timed artificial insemination. J. Anim. Sci. 71:2594-2600.
- Kesler, D.J., H. Khazali and R.J. Favero. 1990. Quantification of steroids via a polymer linked second antibody immunoassay: methods of linking anti-rabbit IgG to poly(styrene). In: Progress in Biochemical Polymers. Ed., C.G. Gebelin and R. Dunn. Plenum publishing co., New York, NY.
- SAS User's guide: Statistics. SAS Institute Inc., Cary, 1985.
- Steel, R.G.D. and J.H. Torrie. 1980. Principles and procedures in Statistics: A Biometrical Approach (2nd Ed.). McGraw-Hill Book Co., New York, N.Y..

Interactions among factors were also assessed (Steel and Torrie, 1980). All analysis were run using the SAS program (SAS user's guide, 1985).

Figure 1. Treatment and Blood Collection Times.



RESULTS

Thirty-four cows had serum progesterone concentrations lower than 1.5 ng/ml at implant removal and one cow that had shown progesterone concentration ≥ 1.5 ng/ml at implant withdrawal was in heat at the time of the second service. Therefore, 16 and 19 cows respectively from 6 mg and 8 mg norgestomet implant group were re-inseminated.

Table 1 reports calving rates obtained after each synchronizing procedure and the combined results.

No detrimental effect on pregnancy rate following removal of implants on the 16th day of insertion was observed.

Table 2 summarizes the effects of the type of second implant on the calving rate to the second artificial insemination.

A greater load of norgestomet (8 mg) effectively suppressed estrus for 16 days and had non-significantly higher calving rate (52.6%) than that observed for cows re-implanted with 6 mg implants (43.7%). This difference was the result of breakthrough estrus (18.7%) reported in the 6 mg norgestomet implanted females.

TABLE - 1. EFFECT OF THE RE-SYNCHRONIZATION OF ESTRUS ON CALVING RATES OF POSTPARTUM BEEF COWS PREVIOUSLY TREATED WITH SYNCRO-MATE B AND ASSOCIATED OR NOT WITH PGF_{2α} PRE-ADMINISTRATION.

	Calving rate							
	1 st AI			2 nd AI			Cumulative	
	N	n	%	N	n	%	n	%
No-PGF _{2α}	28	09	32.1 ^a	18	08	44.4 ^a	17	60.7
PGF _{2α}	28	06	21.4 ^b	17	09	52.9 ^a	15	53.6
Overall	56	15	26.8 ^a	35	17	48.6 ^a	32	57.1

^{a,b} Figures with different superscripts within the same row differ (P<.05).

TABLE - 2. EFFECT OF THE TYPE OF THE 2nd IMPLANT ON THE CALVING RATE TO THE 2nd ARTIFICIAL INSEMINATION OF POSTPARTUM BEEF COWS PREVIOUSLY SUBMITTED TO THE SYNCRO-MATE B PROGRAM.

Implant ¹	Treatment								
	No-PGF _{2α}			PGF _{2α}			Overall		
	N	Calving		N	Calving		N	Calving	
		n	%		n	%		n	%
6 mg	8	3	33.3	8	4	50.0	16	7	43.7
8 mg	10	5	50.0	9	5	55.5	19	10	52.6
Total	18	8	44.4	17	9	52.9	35	17	48.6

¹ No statistically significant (P>.05) differences were found.

EFFECTS OF THE STAGE OF THE ESTROUS CYCLE ON THE CALVING RATE OF POSTPARTUM BEEF COWS SUBMITTED TO ESTRUS SYNCHRONIZATION WITH SYNCRO-MATE B

R. Machado, D.B. Faulkner and D.J. Kesler

SUMMARY

The use of 25 mg of prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) five days prior to the synchronization of estrus with Syncro-Mate B (SMB) treatment displaced cows to metestrus (in 65.5 % of the cyclic cows) at the time of initiation of SMB treatment. Displacement to metestrus, at the time of SMB treatment significantly ($P<.05$) depressed fertility. Evaluation of the data overall demonstrated that cyclic cows synchronized with SMB in the first half of the estrous cycle had significantly ($P<.05$) lower calving rates (20.6%) than cows treated during the second half of the cycle (44.3%).

INTRODUCTION

Short-term exposure to progestogen associated with estrogens (the components of SMB) effectively synchronizes estrus in beef cattle. However, pregnancy rates across trials have been inconsistent and controversy exists about the stage of the estrous cycle at initiation of the treatment on calving rates to the timed artificial insemination. This trial was designed to determine differences in calving rate according to the stage of the estrous cycle when SMB was given to postpartum beef cows.

PROCEDURES

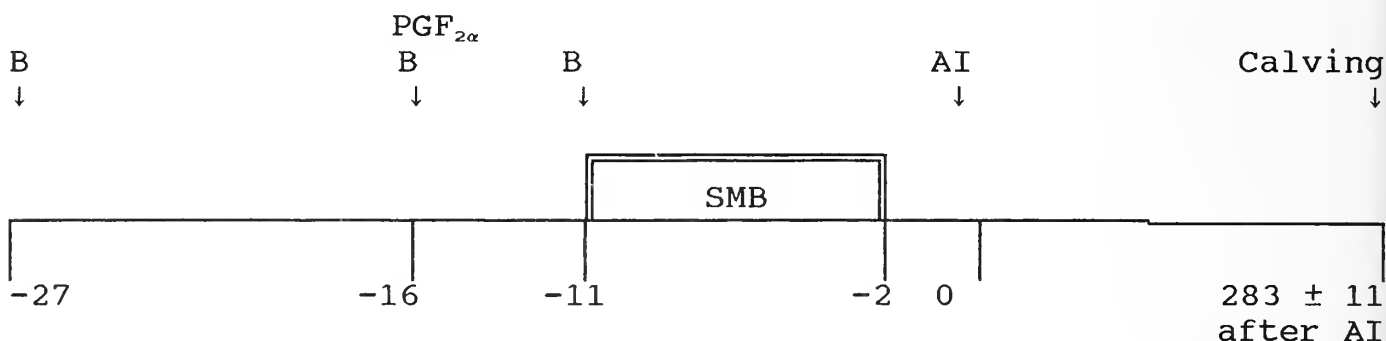
Two-hundred and sixty-four suckled Angus and mixed breed beef cows at two locations averaging 62.78 ± 17.51 days postpartum were synchronized into estrus with a 6 mg silicone norgestomet implant subcutaneously inserted in the ear at the same time as an intramuscular injection of 3 mg norgestomet and 5 mg estradiol valerate was given. Cows were bred by artificial insemination (AI) approximately 48 hours after implant removal. One-hundred and thirty-one (131) cows received 25 mg of prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) as dinoprost tromethamine five (5) days before estrus synchronization. Blood serum was obtained from all cows at strategic dates (Figure 1) to determine estrous cyclic status of cows prior to synchronization, the efficiency of the $PGF_{2\alpha}$ as a luteolytic agent, and the stage of estrous cycle at SMB administration. Serum progesterone concentrations were determined through a validated enzyme linked immunosorbant assay (ELISA; Kesler et al., 1990). Progesterone concentration of 1.5 ng/ml or greater in any of the three samplings was considered to indicate the presence of an active corpus luteum. A decrease in progesterone concentration from ≥ 1.50 ng/ml to < 1.0 ng/ml between

the day of $\text{PGF}_{2\alpha}$ administration and the day of the insertion of the norgestomet implant was taken to indicate that luteolysis had resulted.

Only calvings 283 ± 11 days from the date of the timed artificial insemination were considered to determine calving rates for treated and control groups.

Statistical analysis was proceeded through general linear models procedures for analysis of variances and covariances (Steel and Torrie, 1980). All analyses were run using the SAS program (SAS User's Guide, 1985).

Figure 1. Schedule of Treatments and Blood Collections.



B: Bleeding and determination of progesterone.

$\text{PGF}_{2\alpha}$: 25 mg of prostaglandin IM as dinoprost tromethamine.

SMB: 6 mg norgestomet implant insertion and 5 mg estradiol valerate/3 mg norgestomet injection.

RESULTS

70.4% of cows were cycling at implant insertion and the degree of cyclic activity was related to days postpartum. On the average, cyclic cows were at 67.6 ± 16.1 days postpartum and anestrus cows were 51.5 ± 16.4 days postpartum at the initiation of treatment.

Luteolysis took place in 65.5% (38 cows) of $\text{PGF}_{2\alpha}$ -treated cows ($n=58$) which were bearing corpora lutea at the time of injection and spontaneous regression occurred in 40.7% (24/59) of control cows ($P<.05$).

Table 1 shows effects of treatment and location on calving rate. Differences between treatments in calving rate were significant ($P<.05$) and no interactions were significant ($P>.40$).

The effects of the demise of the corpus luteum is presented in the

Table 2. Overall, the demise of corpus luteum led to lower calving rate ($P < .05$), which might indicate that cows in estrus or metestrus had depressed fertility to the appointed artificial insemination after estrus synchronization. However, the $\text{PGF}_{2\alpha}$ -induced corpus luteum regression severely depressed fertility (7.9%) whereas the spontaneous regression of corpus luteum did not show the same effect.

Table 3 presents the effect of the stage of the estrous cycle at initiation of Syncro-Mate B treatment on the fertility of cyclic cows. Induced regression of corpus luteum by means of $\text{PGF}_{2\alpha}$ displaced cows at luteal stage ($n=38$) to metestrus at the time of Syncro-Mate B treatment and fertility was significantly ($P < .05$) depressed (7.9%) whereas spontaneous regression did not affect calving rate (50.0%).

The outcome of this experiment shows significant influence of the stage of estrous cycle on calving rate of postpartum suckled beef cows. Higher fertility ($P < .05$) for cows treated on the second ($35/79 = 44.3\%$) than cows on the first ($22/107 = 20.6.3\%$) half of the estrous cycle was observed.

DISCUSSION AND CONCLUSIONS

The mechanics of the synchronizing treatment with Syncro-Mate B relies upon the fact that the progestogen (norgestomet) acts as an estrus suppressor and the estrogen (estradiol valerate) inhibits corpus luteum formation or initiates the regression of pre-existing corpora lutea. Failure of the luteolytic action of estradiol valerate when administered during metestrus have been suggested (Pratt et al., 1991) and calving rates are negatively affected (Sanchez et al., 1993). On the other hand, Brink and Kiracofe reported higher conception rates for cows synchronized late (more than 11 days) in the estrous cycle.

In the present trial, cyclic cows treated with SMB in the first half of the cycle had lower ($p < .05$) calving rate ($22/107 = 20.6\%$) than cows synchronized during the second half of the cycle ($35/79 = 44.3\%$). Moreover, the most dramatic decay in fertility was observed for cows treated between days 1 and 5 (metestrus) of the estrous cycle ($8/49 = 16.3\%$).

REFERENCES

- Brink, J.T. and G.H. Kiracofe. 1988. Effect of estrous cycle stage at Syncro-Mate B treatment on conception and time to estrus in Cattle. *Theriogenology* 29:513-518.
- Kesler, D.J., H. Khazali and R.J. Favero. 1990. Quantification of steroids via a polymer linked second antibody immunoassay: methods of linking anti-rabbit IgG to poly(styrene). In: *Progress in Biochemical Polymers*. Ed., C.G. Gebelin and R.

Dunn. Plenum publishing co., New York, NY.

Pratt, S.L., J.C. Spitzer, G.L. Burns and B.B. Plyler. 1991. Luteal function, estrous response, and pregnancy rate after treatment with norgestomet and various dosages of estradiol valerate in suckled cows. J. Anim. Sci. 69:2721-2721.

Sanchez, T., M.E. Wehrman, E.G. Bergfeld, K.E. Peters, F.N. Kojima,, A.S. Cupp, V. Mariscal, R.J. Kittok, R.J. Rasby and J.E. Kinder. 1983. Pregnancy rate is greater when the corpus luteum is present during the period of progestin treatment to synchronize time of estrus in cows and heifers. Biol. Repro. 49:1102-1107.

SAS User's guide: Statistics. SAS Institute Inc., Cary, 1985.

Steel, R.G.D. and J.H. Torrie. 1980. Principles and procedures in Statistics: A Biometrical Approach (2nd Ed.). McGraw-Hill Book Co., New York, N.Y..

TABLE - 1. EFFECT OF THE ADMINISTRATION OF PGF_{2α} PRIOR TO THE ESTRUS SYNCHRONIZATION PROCEDURE ON THE CALVING RATE OF POSTPARTUM BEEF COWS ACCORDING TO LOCATION.

	Treatment								
	Control			PGF _{2α}			Overall		
	N	Calving		N	Calving		N	Calving	
		n	%		n	%		n	%
Location									
DSAC	100	32	32.0	98	25	25.5	198	37	28.8
Urbana	33	12	36.4	33	06	18.2	66	18	27.3
Total	133	44	33.1 ^a	131	31	23.7 ^b	264	75	28.4
Cyclic Activity									
Cyclic	95	34	35.8	91	22	23.1	186	56	30.1
Anestrous	38	10	26.3	40	09	22.5	78	19	24.3

¹ There was no statistically significant differences (P>.05) between locations or between cyclic status.

^{a,b} Means with different superscript letters differ (P<.05).

TABLE - 2. EFFECT OF CORPUS LUTEUM DEMISE¹ BEFORE THE INITIATION OF THE ESTRUS SYNCHRONIZATION PROGRAM² ON THE CALVING RATE OF POSTPARTUM SUCKLED BEEF COWS.

		Corpora lutea status					
	Active ³	Demised			Persisted		
		calving			calving		
		n	n	rate (%)	n	n	rate (%)
Control	59	24	12	50.0 ^a	35	16	45.7 ^a
PGF _{2α}	58	38	03	7.9 ^b	20	08	40.0 ^a
Overall	117	62	15	24.2 ^b	55	24	43.6 ^a

¹ Corpus luteum regressed when concentration of progesterone in the serum dropped from 1.5 ng/ml to less than 1.0 ng/ml since five days before the initiation of the estrus synchronization treatment.

² The program consisted of a silicone ear implant containing 6 mg of norgestomet and the injection of 3 mg of norgestomet and 5 mg of estradiol valerate at the time of implant insertion.

³ Corpus luteum was considered active when serum concentration of progesterone was equal to or higher than 1.5 ng/ml.

^{a,b} Means with different superscript letters differ (P<.05).

TABLE - 3. CALVING RATES OF POSTPARTUM BEEF COWS SYNCHRONIZED WITH SYNCRO-MATE B[®] ASSOCIATED WITH OR WITHOUT PGF_{2α} PRETREATMENT ACCORDING TO CYCLIC ACTIVITY¹ AND STAGE OF THE ESTROUS CYCLE².

Cyclic	Control		PGF _{2α}		Combined	
	Calving		Calving		Calving	
	n	(%)	n	(%)	n	(%)
Anestrous	10/38	26.3	09/40	22.5	19/78	24.3 ^b
Stage of the cycle ³						
day 1 to 5	01/04	25.0	07/45	15.6	08/49	16.3 ^b
day 6 to 10	07/32	21.2	07/26	26.9	14/58	24.1 ^b
day 11 to 17	15/35	42.8	08/20	40.0	23/55	41.8 ^a
day 18 to 0	12/24	50.0	-	-	12/24	50.0 ^a

¹ Cows were considered cycling when serum progesterone concentration was ≥ 1.5 ng/ml at least once in a series of three collections comprised of a 16 day interval.

² Estrous cycle length was considered to be 21 days with luteal phase (progesterone concentration ≥ 1.5 ng/ml) between days 6 and 17 of the cycle.

³ Stage of the cycle at Syncro-Mate B[®] treatment.

^{a,b} Means with different superscript letters within columns differ (P<.05)

SECRETION OF NORGESTOMET FROM SILICONE (POLYDIMETHYLSILOXANE) IMPLANTS AND THE SUPPRESSION OF ESTRUS IN BEEF COWS

R. Machado and D.J. Kesler

SUMMARY

The daily secretion rate of norgestomet from silicone implants impregnated with either 6 mg or 8 mg of norgestomet was determined by validated in vitro and in vivo assays. In addition, the ability of these implants to suppress estrus in postpartum beef cows was assessed. It was established that at least 136 μg of norgestomet should be released daily from silicone implants to effectively suppress estrus behavior in beef cows. An initial load of norgestomet as high as 8 mg suppressed estrus for 16 days. On the contrary, cows implanted with 6 mg norgestomet implants started to show breakthrough estrus beginning day 12 after insertion.

INTRODUCTION

Control of estrus and ovulation can be accomplished either by shortening or lengthening the luteal phase of estrous cycle. Norgestomet is a potent progestogen that blocks estrus behavior in cows when administered as a subcutaneous implant. Nonetheless, the development of a sustained release steroid implant requires the determination of minimum amount of delivery in which the desired biological response takes place.

The main goals of this study are to determine the secretion rate of norgestomet daily released from polydimethylsiloxane (silicone) implants impregnated with different amounts of the steroid and compare the secretion rate with the behavioral profile of cows. Furthermore, a threshold for the norgestomet effective suppressing activity towards estrous behavior is to be established.

PROCEDURES

The ability of silicone implants loaded either with 6 mg (surface area = 166 mm^2) or 8 mg (surface area = 221 mm^2) of norgestomet to release the steroid and thus suppress estrus in beef cows was assessed through three different approaches, as follows.

In vitro secretion assay. This consisted of a bovine serum culture system maintained at 37 °C for 16 days. Culture medium was changed every 24 hours. Serum was individually extracted for norgestomet and norgestomet concentration determined spectrophotometrically (Kesler and Favero, 1989). Norgestomet secretion rate was determined on a daily basis and used to generate regression equations.

In vivo secretion assay. Complete extraction of norgestomet from

new implants (total content) and implants left in situ for 16 days (in vivo secretion) was performed. The difference was considered the amount secreted in vivo. In addition, determination of remaining norgestomet in the implants previously used in the in vitro assay was performed (in vitro secretion).

Behavioral trial. This involved 35 non-pregnant beef cows which had been initially synchronized with the Syncro-Mate B program and that on day 5 were randomly allotted in two groups. Seventeen cows received a 6 mg norgestomet implant and 18 cows received a 8 mg implant. Estrus behavior was determined twice daily until the withdrawal of the implant.

Statistical analyses. Statistical tests included analysis of regression for the daily release of norgestomet according to each type of implant studied, analysis of variance for repeated measures to determine time-wise differences in the mass of norgestomet delivered and its rate of release. The Chi-square test was employed to compare observed frequencies of cows in estrus (Steel and Torrie, 1980). All statistical analysis were performed through the SAS statistical program.

RESULTS

The daily release rate (mass of norgestomet daily released/mass in the core of the implant) was non-significantly ($P > .05$) higher ($6.7 \pm 0.4\%$) for the 6 mg compared to 8 mg ($6.1 \pm 0.5\%$) implant. Figure 1 shows the amount (μg) of norgestomet daily released. The greater surface area of the 8 mg implant ensured an also greater daily release of the steroid from the implant.

The outcome of the in vivo assay is shown in Table 1. In order to account for differences in the kinetic profile of norgestomet deliver related to the systems of evaluation (in vitro, in vivo), a correction factor was determined (Table 1). Figure 1 shows not only actual data, but also a scale with the correspondent corrected values. In addition, equations to predict release are provided. The usefulness of the regression equations is related with the fact that it beccmes possible to predict the duration of the effectiveness of any of the implants herein assessed.

Three cows implanted with the 6 mg norgestomet capsule exhibited breakthrough estrus. Cows implanted with 8 mg capsules did not display estrus within the 16 day period while implants were in place. Therefore, 8 mg norgestomet implants were 100% (18/18) effective in suppressing estrus in the non-pregnant re-synchronized cows and 6 mg implants only achieved 82.3% (13/17) of efficacy for the same period of time.

Table 2 combines behavioral trial observations with the outcomes from both the in vitro assay and the in vivo determination of norgestomet delivery. The appearance of the first breakthrough estrus occurred on day 13 after implants insertion and coincided

with an corrected norgestomet release of 121 μg and an expected release of 124 μg .

As shown in the Table 1 and Figure 1 breakthrough estrus took place when predicted daily release of norgestomet decayed to 124 μg (13th day) or below. Moreover, a expected release of 137 μg sufficed to keep cows implanted with 6 mg capsules from estrus. Such a result was further reinforced by the fact that no cows receiving 8 mg norgestomet implants showed estrus within the 16 day period and the lowest secretion expected would take place on the 16th day since insertion and would be 136 μg . Therefore, it can be established that 136 μg of norgestomet secreted daily from implants will suppress estrus behavior in cattle. This conclusion is coherent with the actually measured and corrected amount of steroid delivered from the 6 mg norgestomet implant because even when norgestomet was erratically released on day 11, estrus was not manifested and the secretion was 141 μg . On the other hand, as actual secretion reached a daily value as low as 121 μg (Figure 1) breakthrough estrus was displayed.

CONCLUSIONS

The secretion of norgestomet from silicone implants differed according to the initial load impregnated and initial surface area of the cylinder. Implants containing 8 mg of norgestomet were capable to effectively suppress estrus in postpartum beef cows submitted to estrus re-synchronization. Implants with 6 mg of norgestomet were not efficient in inhibiting estrus for longer than 12 days in situ. Estrus was suppressed when the expected daily release of norgestomet was at least 136 μg .

REFERENCES

- Kesler, D.J. and R.J. Favero. 1989. In vitro and in vivo secretion of norgestomet from matrix silicone and hydron implants and pregnancy rates of females synchronized with norgestomet implants. In: Proc. 16 Int. Symposium On Controlled Release of Bioactive Materials. pp 435-436.
- SAS User's guide: Statistics. SAS Institute Inc., Cary, 1985.
- Steel, R.G.D. and J.H. Torrie. 1980. Principles and procedures in Statistics: A Biometrical Approach (2nd Ed.). McGraw-Hill book Co., New York, N.Y..

FIGURE - 1. PREDICTED DAILY RELEASE (μg) OF NORGESTOMET FROM THE IMPLANTS.

Implant load	Linear Equation ¹	r	R ²
6 mg	$Y = -17.8059 X + 402.2250$	- 0.9597	0.9210**
8 mg	$Y = -17.5603 X + 468.3250$	- 0.9350	0.9082**

¹ Y = mass of norgestomet released and X = day of incubation
** P<.01

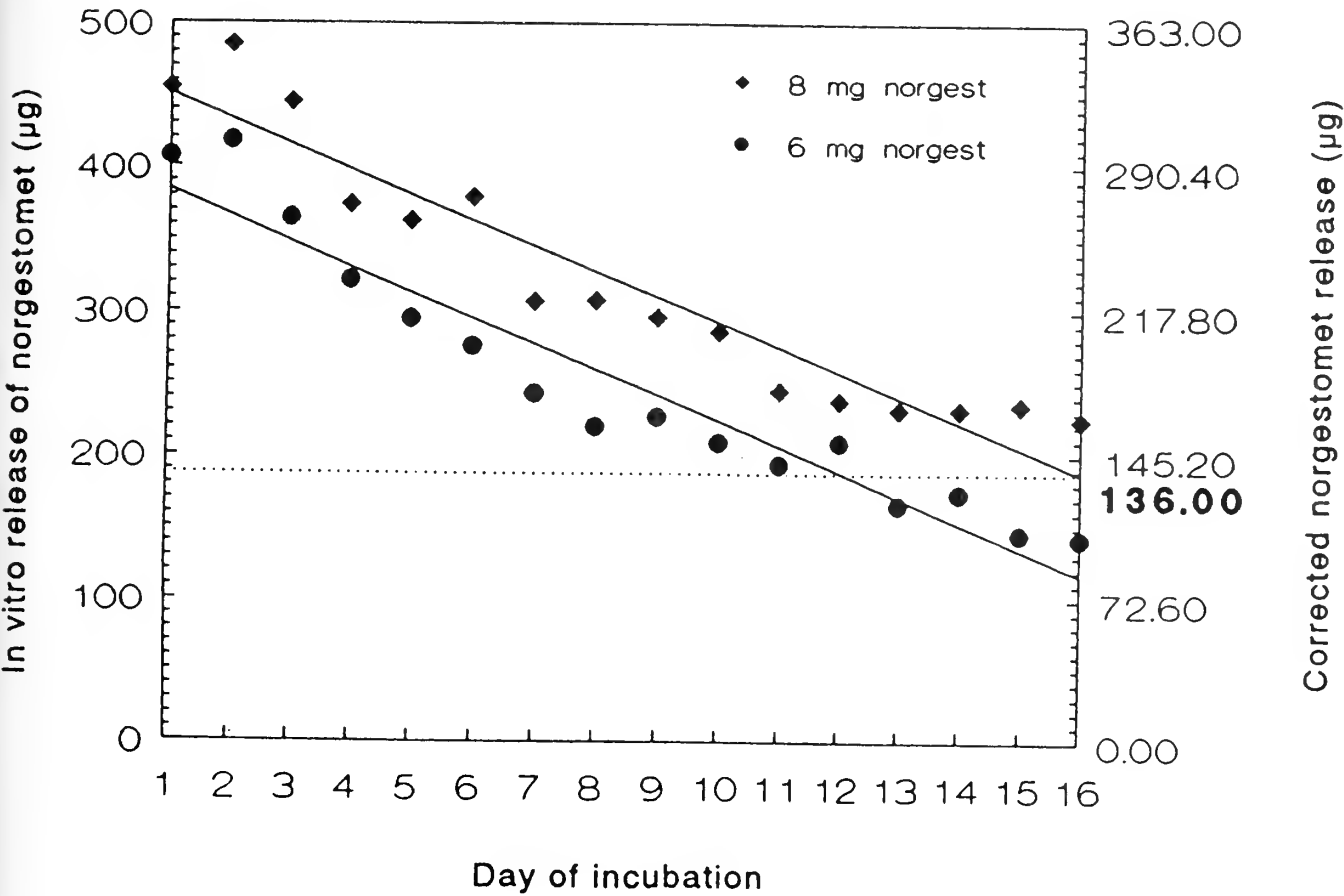


TABLE - 1. TOTAL CONTENT (mg), IN VIVO AND IN VITRO SECRETION (mg) OF NORGESTOMET FROM SILICONE IMPLANTS ACCORDING TO INITIAL STEROID LOAD.

Norgestomet content (mg)	Type of implant			
	6 mg ¹		8 mg ²	
	Mean \pm sd	CV(%)	Mean \pm sd	CV(%)
Total ³	6.21 \pm 0.09	1.4	8.33 \pm 0.16	3.8
<u>In vivo</u> recuperation ⁴	3.17 \pm 0.10	3.1	4.57 \pm 0.33	7.2
<u>In vivo</u> secretion ⁵	3.04		3.76	
<u>In vitro</u> recuperation ⁶	2.02 \pm 0.11	5.4	3.15 \pm 0.24	7.2
<u>In vitro</u> secretion ⁷	4.19		5.18	
<u>In vitro</u> secretion ⁸	4.01		5.46	
<u>In vitro</u> / <u>In vivo</u> ratio ⁹	4.19/3.04 = 1.378 5.18/3.76 = 1.378			

¹ Implant designed to contain 6 mg of norgestomet.

² Implant designed to contain 8 mg of norgestomet.

³ After complete extraction with methanol at 37 °C for 6 days.

⁴ Content remaining in the implant after left 16 days in situ.

⁵ Total content minus in vivo recuperation.

⁶ Content remaining in the implant after a 16 days in vivo assay.

⁷ Total content minus in vitro recuperation.

⁸ Cumulative in vitro secretion observed after a 16 in vitro assay.

⁹ Ratio used to compute the correction factor for in vivo kinetics.

TABLE - 2. DETECTION OF BREAKTHROUGH ESTRUS ACCORDING TO DAY OF RE-SYNCHRONIZATION AND CORRECTED AMOUNTS OF NORGESTOMET RELEASED FROM THE POLYDIMETHYLSILOXANE IMPLANT LOADED WITH 6 mg OF NORGESTOMET.

Cow ID No.	Breakthrough estrus	Norgestomet release (μ g)	
		Actual	Predicted
7073	13 th	121	124
7435	15 th	106	98
5205	16 th	104	85



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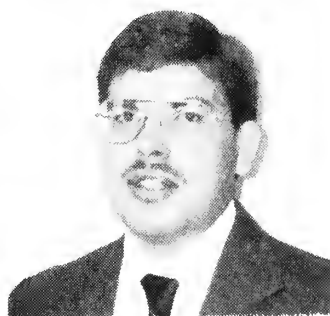


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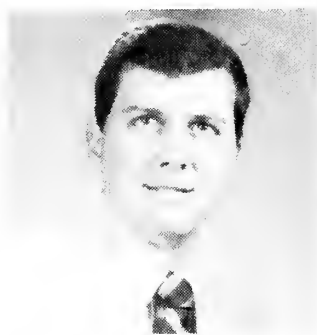
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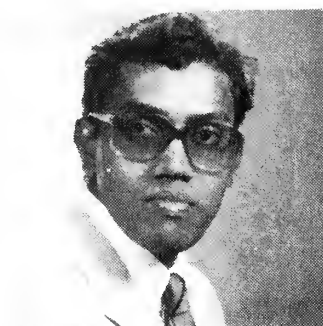
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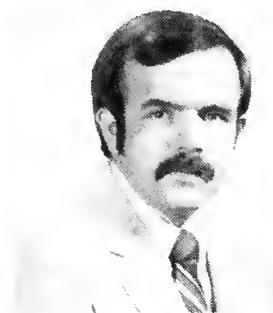
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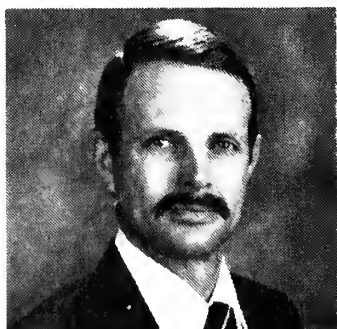
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THANK YOU

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THE DEPARTMENT OF ANIMAL SCIENCES
University of Illinois

Dennis R. Campion, Head of Department

On October 21, 1994 there was an unveiling of *Origins*, a monumental, stainless-steel bas-relief which is affixed to the Animal Sciences Laboratory. This artwork is part of the Art-in-Architecture program of the Illinois Capital Development Board. The artist is Peoria-based Mr. Preston Jackson. *Origins* is a general depiction of the evolution and diversity of animals - as such it captures the nature of the programs in Animal Sciences. Misty Doan, a junior from Olney, and Chad Ruppert, a junior from Nokomis assisted with the unveiling. Misty is from a mixed farm and Chad is from a beef farm here in Illinois. While the sculpture may capture the past, it is our students who represent the future.

With the pressures upon the beef industry in Illinois today, the future appears especially challenging. Our research and extension programs at the University of Illinois remain targeted on providing information that will help the beef industry remain competitive. This Beef Report is but one example of our efforts to provide timely information. In addition to this and other established methods we are exploring new ideas and new ways of communicating with you. For example, the establishment of a Center for Livestock Information is under discussion. This concept would allow the use of one phone number through which calls could be directed to the appropriate extension specialist or extension educator. Along with the Center concept, electronic bulletin boards and electronic newsletters are being contemplated. Roundtable discussions of policy issues affecting the industry could be effectively handled through the Center. And the possibilities go on. Would such a Center benefit the beef producer? Are there better ways that the University can provide information? Your input on these questions would be sincerely appreciated.

As I mentioned above we are always eager to have your input. It is our sincere pleasure to be a part of the beef industry of this state. We appreciate your interest and support.

EXPLANATION OF STATISTICAL ANALYSIS USED IN THIS BEEF REPORT¹

D. D. Buskirk

Evaluation of treatments and drawing conclusions about a population on the basis of sample data requires statistical analysis. Statistical analysis is necessary because all animals do not perform identically. For example, cattle receiving treatment X may have a greater average daily gain than those receiving treatment Y, however because there is variability within the groups the observed difference between groups may or may not be due to the treatments. Statistical analysis allows researchers to calculate the probability that such differences are from chance rather than the treatment.

In this report you may see the notation ($P < .05$). This means that the probability of the observed difference being due to chance is less than 5%. If two averages (means) are referred to as significantly different ($P < .05$), the probability is less than 5% that these two means are different strictly by chance. In other words, the probability is greater than 95% that the difference was caused by the treatments.

Means may be reported as $2.5 \pm .1$, where 2.5 is the mean and .1 is the standard error (SE). The standard error describes variability in a set of data. There is a 68% probability that the true mean (the mean if we could measure all animals) will be within one SE of the sample mean. There is a 95% probability that the true mean will be within two SE of the sample mean. In this example, there is a 68% probability that the true mean is between 2.4 and 2.6 ($2.5 \pm .1$), and a 95% probability that it is between 2.3 and 2.7.

Correlations may be reported in some articles. A correlation is a measure of the relationship between two traits. The relationship may be positive (both traits get larger or smaller together) or negative (as one trait gets larger the other gets smaller). A perfect correlation is +1 or -1. If there is no relationship the correlation is 0. A high correlation does not necessarily mean that one trait causes the other.

Much of the statistical analysis calculated for this report has been done using the Statistical Analysis System (SAS). SAS is an exceptionally powerful computer program for analyzing experimental data. The research presented in this beef report includes statistical analysis to increase confidence that can be placed in the results.

¹In part from 1993 Kansas Cattlemen's Day Report

BEEF CATTLE PERFORMANCE AND FORAGE CHARACTERISTICS OF ROTATIONALLY GRAZED TALL FESCUE-RED CLOVER AND TALL FESCUE-ALFALFA PASTURES

S. E. Myers, D. B. Faulkner, D. D. Buskirk, J. W. Castree, and D. F. Parrett

SUMMARY

Cow-calf performance and diet composition were compared under rotational grazing of established tall fescue-red clover (**TF-RC**) and tall fescue-alfalfa (**TF-A**). Eighty cow calf pairs were randomly allotted to the two forage mixtures with three replications. Paddocks were grazed using a 6-paddock rotation so that paddocks were grazed for 6 d and rested for 30 d throughout the 121 d trial. Put-and-take animals were used to evaluate stocking rate. One ruminally fistulated cow grazed each pasture to obtain intake estimates from rumen evacuation samples on d 0, 6, 36, 42, 72, 78, 108 and 114. Standing forage was sampled at the beginning and end of grazing in paddock 1 to obtain composition of grazed forage. Cow gain ($P = .27$) and body condition score change ($P = .59$) were not different due to treatments. However, TF-A improved calf gains by 11.5% ($P < .05$) compared to TF-RC. Both treatments were grazed at similar stocking rates ($P = .81$). Calf gain per ha for the TF-A pastures tended to be 10% higher ($P = .15$) than that for TF-RC. This is due to the improved calf performance on TF-A with similar stocking rates. Tall fescue-alfalfa was lower in NDF and ADF ($P < .01$), and higher in CP ($P < .01$) on day 1. After grazing, TF-A was lower in NDF ($P < .05$), and higher in CP ($P < .01$). Both TF-RC and TF-A effectively maintained cow performance. The TF-A mixture resulted in improved calf gain.

INTRODUCTION

Rotational grazing enables a producer to increase stocking rate of pastures. However, results can vary greatly depending upon climate, soil, topography, weather and type of forage and animals used. Grasses will generally stay in pastures for several years if a good fertility and grazing management program is maintained. Red clover and alfalfa, on the other hand, tend to be relatively short-lived and will need to be reseeded periodically. When seeded with tall fescue, legumes can be easily maintained and help dilute the level of endophyte present in the mixture. Stocking rate and gain per ha are generally improved by the incorporation of legumes into the sward (Burns et al., 1973; Petritz et al., 1980). The objectives of the following study was to compare the effects of rotational grazing tall fescue-red clover and tall fescue-alfalfa on animal performance, diet composition and characteristics of available forage.

MATERIALS AND METHODS

The experiment was conducted at the University of Illinois Orr Center Beef Unit located near Baylis, IL, from mid-May through mid-September, 1993. Eighty Angus

x Simmental cow/calf pairs (cows = 528.8 ± 21.4 kg, calves = 117.2 ± 7.9 kg) were randomly allotted to six pastures. Two treatments were assigned to six pastures with three replications per treatment. The two treatments were tall fescue-red clover (TF-RC) and tall fescue-alfalfa (TF-A). Pastures were divided into six equal-area paddocks with a single strand of polywire electrified by a solar-powered fence charger for each pasture. Each paddock was grazed for 6 d and rested for 30 d of regrowth. All animals were rotated to new paddocks between 0700 and 0900. Animals had continuous access to water and mineral. Ten of the cow-calf pairs originally allotted were used as put-and-take animals and were added or removed to maintain a forage density height between 3 and 9 cm after the sixth day of grazing as measured with a rising plate-meter (Michell and Large, 1983).

Tall fescue-red clover pastures were approximately 1.9 ha and TF-A pastures were approximately 1.7 ha. Tall fescue-red clover pasture forage consisted of 50% tall fescue, 30% red clover, and 20% other; TF-A consisted of 80% alfalfa, 15% other, and 5% tall fescue by visual estimate of trained evaluators for all pastures. Prior management consisted of forage production prior to the onset of the experiment. All tall fescue pastures were developed in 1990. Alfalfa pastures were established during August and September 1990, using a mixture of seed (F.S. Growmark, WL 317; Ciba Geigy Seed Division, Funks G 2852 and 2833; Pioneer, Pioneer 5472; and Dekalb Plant Genetics, DK 125). Red clover pastures were seeded in March 1993 with medium red clover seed (F.S. Growmark, Marathon).

Initial and final individual calf and cow weights were taken after a 16-h withdrawal from water. Gain, stocking rate and gain per ha were then calculated. Put-and-take cow-calf pairs and bulls were not used in gain calculations but included in stocking rate determination. Body condition scores (BCS; 1 to 9 scale) were assigned at initial and final weighing by two experienced evaluators. Each cow's BCS is the average of the two scores.

One ruminally fistulated mature cow was placed in each pasture. The fistulated cows were included in the calculation of stocking densities and stocking rates, but were not included in the gain or BCS determinations. Reticulorumen samples were collected at the beginning and ending of grazing paddock 1 during four sampling periods (d 0, 6, 36, 42, 72, 78, 108, and 114). On sampling days, the six ruminally fistulated cows were caught between 0600-0800 and removed from their assigned paddocks and brought to a central working area. Animals were restrained and the solid reticulorumen contents of each animal were removed by hand and the liquid portion of the rumen contents was removed using a wet-dry vacuum. The inner walls of the reticulorumen were rinsed twice with water and the rinse water was removed with the vacuum. Non-fistulated animals were rotated and each cow returned to their assigned paddock and allowed to graze freely for approximately 1 to 2 h. At the end of the grazing period 1 kg of extrusa sample was removed, bagged, and cooled. The original digesta was replaced and the cows were returned to their respective pastures. Samples were then frozen at -20° C. Each fistulated cow grazed the same pasture for sampling throughout the trial.

A rising plate meter was used to estimate forage availability. Forage availability of each paddock was estimated as the mean of 20 random measurements taken at the beginning and ending of grazing each paddock to provide a single before and after grazing estimate of forage availability for each of three rotations.

Reticulorumen extrusa samples were lyophilized, ground in a Wiley mill to pass a 1-mm screen, and analyzed for DM, OM and Kjeldahl N (AOAC, 1980). Samples were also analyzed for NDF and ADF (Goering and Van Soest, 1970). Crude protein of the extrusa samples was calculated to be 6.25 times the Kjeldahl N concentration. All NDF, ADF and CP concentrations are expressed on an OM basis to remove any interference from soil or mineral mix ingestion. Reticulorumen extrusa samples were composited by pasture and ergovaline was quantified by a HPLC procedure (Rottinghaus et al., 1991).

Statistical Analysis. Least square means for performance data were calculated using analysis of variance and the GLM procedure of SAS (1990) with pasture as the experimental unit. The model statement contained cow and calf gain, cow BCS, stocking rate, and gain per ha as dependent variables and replicate, and treatment as independent variables. The forage compositional data were analyzed using a split-plot analysis with NDF, ADF, and CP concentration as dependent variables and replicate, treatment, period, day, and their interactions as independent variables, where day is either the first or last day of grazing paddock 1. A regression equation was developed for available forage on rising plate meter height using the REG procedure of SAS (1990). Forage availability was analyzed using a split-plot analysis with forage availability as the dependent variable and replicate, treatment, rotation, day, and their interactions as independent variables. Treatment differences were evaluated using linear and quadratic orthogonal contrasts.

RESULTS

The effect of treatment on the performance traits measured are presented in Table 1. For the cows initial and final BW, weight change, gain, initial and final BCS, and BCS change were not different ($P > .23$) due to treatment. These data indicate that cows rotational grazing TF-RC perform similarly to those on TF-A. Pregnancy rate was high and no difference was observed due to treatment, because there was only one open cow.

Calf performance was improved for calves grazing TF-A compared to TF-RC. Calves on the TF-A treatment exhibited 11.5% greater gain ($P < .05$) than calves grazing TF-RC. This may have been due to the higher proportion of legumes in the TF-A mixture. This is supported by the lower ($P = .02$) ergovaline concentration for the TF-A compared to the TF-RC treatment (16 ± 30 vs. 195 ± 30 ppb, respectively). Mean stocking rate of the treatments were 3.00 and 2.98 (cow-calf pairs/ha) for TF-RC and TF-A, respectively. Calf gain per ha for the TF-A pastures tended to be 10% higher ($P = .15$) than that for TF-RC. This is due to the improved calf performance on TF-A with similar stocking rates.

Treatment \times beginning or end of grazing interactions were present ($P < .05$) for all components of the diet. The composition of standing forage at the beginning and end of grazing for each of the two treatments is listed in Table 2. Tall fescue-alfalfa pastures were higher quality due to lower ($P < .05$) NDF and ADF and higher CP concentrations than TF-RC before grazing. These values correspond to the forage composition available to the cow-calf pairs at the beginning and end of grazing paddock 1 for the four periods. The improved forage composition before grazing explains the increased gain of calves in the TF-A treatment. Forage quality dropped substantially in both treatments from beginning to end of grazing a paddock ($P < .05$); however, TF-A usually had higher quality. The TF-A in this study was higher quality (NDF and CP of 40.0 and 21.1 compared to 58.0 and 15.0) than was observed by Bertelson et al. (1993). This may have been due to the wet growing conditions for this study since both studies were conducted at the same location.

Time \times beginning or end grazing interactions were present ($P < .01$) for components of reticulorumen samples. Forage composition at the beginning of grazing was lower in NDF, ADF and higher in CP ($P < .01$) in period 2 (Table 3). Neutral detergent fiber was increased ($P < .01$) in period 4. These variations may be due to moisture and temperature effects, resulting in small differences. With the exception of higher quality during period 2, forage quality was similar during the grazing season. No differences were observed in composition of grazed forage at the end of grazing periods.

Treatment \times time interactions were present ($P < .05$) for components of reticulorumen samples. Cow-calf pairs grazing TF-A consumed diets that were lower in NDF and higher in CP concentrations ($P < .05$) than the diets consumed by cow-calf pairs grazing TF-RC (Table 4). Selection of a diet lower in NDF corresponds to a lower percentage of NDF in the available forage in TF-A pastures (Table 3). However, dietary concentration of ADF did not differ ($P > .07$) among treatments. No differences in NDF, ADF, and CP were observed for TF-RC over time. Tall fescue-alfalfa declined in quality over time as indicated by the higher fiber and lower CP concentrations ($P < .05$); however it was still as good as or better than TF-RC. The higher CP and lower fiber concentrations could partially explain greater gains by calves grazing TF-A since calves tend to become more dependent on the forage quality when the dams milk production declines.

A treatment \times rotation \times beginning and end grazing interaction for forage availability is shown in Table 5. Forage available at the beginning of grazing decreased ($P < .05$) with each rotation regardless of treatment. There was more forage available in rotation 1 at the end of grazing, indicating an insufficient stocking rate at the beginning of the trial prior to adjusting stocking rate. The increased maturity of the forage decreased the quality in the paddocks by the end of the first rotation. One alternative would have been to harvest the paddocks to be grazed last to prevent them from getting too mature.

In this study, above average rainfall resulted in a considerable amount of trampling and decreased forage availability. This is supported by lower rising plate meter measurements near the end of the trial.

CONCLUSIONS

The reduced performance of cattle grazing tall fescue can be offset by interseeding legumes which dilute the endophyte, and improve forage quality. Both red clover and alfalfa are effective as legume supplements in a tall fescue pasture to provide a high quality forage for beef cows. The alfalfa improved calf performance compared to the red clover. This may be a reflection of more alfalfa in the forage mixture or increased milk production due to higher quality forage.

Literature Cited

- AOAC. 1980. Official Methods of Analysis (13th Ed.). Association of Official Analytical Chemists. Washington, D.C.
- Bertelsen, D. B., D. B. Faulkner, D. D. Buskirk, and J. W. Castree. 1993. Beef cattle performance and forage characteristics of continuous, 6-paddock, and 11-paddock grazing systems. *J. Anim. Sci.* 71:1381.
- Burns, J. C., L. Gode, H. D. Gross, and A. C. Linnerude. 1973. Cow and calf gains on ladino clover-tall fescue and tall fescue, grazed along with coastal bermudagrass. *Agron. J.* 65:877.
- Goering, H. K. and, P. J. Van Soest. 1970. Forage Fiber Analyses (Apparatus, reagents, procedures and some applications). *Agric. Handbook* 379. ARS, USDA, Washington, DC.
- Michell, P., and R. V. Large. 1983. The estimation of herbage mass of perennial ryegrass swards: a comparative evaluation of a rising-plate meter and a single probe capacitance meter calibrated at and above ground level. *Grass Forage Sci.* 38:295.
- Petritz, D. C., V. L. Lechtenberg, and W. H. Smith. 1980. Performance and economic returns of beef cows and calves grazing grass-legume herbage. *Agron. J.* 72:581.
- Rottinghaus, G. E., G. B. Garner, C. N. Cornell, and J. L. Ellis. 1991. HPLC method for quantitating ergovaline in endophyte-infested tall fescue: seasonal variation of ergovaline levels in stems with leaf sheaths, leaf blades, and seed heads. *J. Agric. and Food Chem.* 39:112.
- SAS. 1990. SAS/STAT User's Guide. SAS Inst., Cary, NC.

TABLE 1. PERFORMANCE TRAITS OF BEEF COWS AND CALVES ROTATIONALLY GRAZED ON TALL FESCUE-RED CLOVER AND TALL FESCUE-ALFALFA (N = 3)

Item	Tall Fescue		SEM
	Red Clover	Alfalfa	
Cow			
Initial weight, kg	532.3	518.4	16.9
Final weight, kg	514.9	525.6	7.4
Weight change, kg	-17.4	7.2	11.4
Gain, kg/d	-0.14	0.06	0.10
Initial BCS ^a	5.63	5.53	0.04
Final BCS ^a	5.07	5.23	0.30
BCS change ^a	-0.57	-0.30	0.30
Calf			
Initial weight, kg	111.63	122.62	4.18
Final weight, kg	206.21 ^b	227.62 ^c	2.85
Weight change, kg	94.6 ^b	105.1 ^c	1.4
Gain, kg/d	.78 ^b	.87 ^c	.01
Stocking Rate, pairs/ha	3.01	2.98	.06
Calf Gain, kg/ha	284.4	312.5	8.6

^aBody Condition Score (1 = emaciated, 9 = extremely fat).

^{b,c}Least squares means in a row with different superscripts differ (P < .05).

TABLE 2. COMPOSITION OF AVAILABLE FORAGE AT THE BEGINNING AND END OF GRAZING Paddock 1 FOR TALL FESCUE-RED CLOVER AND TALL FESCUE-ALFALFA (N = 12)

Item	Tall Fescue		SEM
	Red Clover	Alfalfa	
Composition beginning	-----	-----	
NDF	58.3 ^a	40.0 ^b	1.7
ADF	36.0 ^a	28.7 ^b	1.2
CP	15.7 ^a	21.1 ^b	0.4
Composition end			
NDF	72.0 ^c	66.6 ^d	1.7
ADF	42.1 ^c	48.3 ^d	1.2
CP	11.1 ^c	13.7 ^d	0.4

^{a,b,c,d}Least squares means in a row or for each nutrient within a column with different superscripts differ ($P < .05$).

TABLE 3. COMPOSITION OF TALL FESCUE-RED CLOVER AND TALL FESCUE-ALFALFA OVER TIME (N = 6)

Item	Period				SEM
	1	2	3	4	
Composition beginning	-----	-----	-----	-----	
NDF	48.8 ^{ab}	43.9 ^a	48.7 ^{ab}	55.2 ^b	2.4
ADF	32.0 ^{ab}	28.6 ^a	34.2 ^b	34.6 ^b	1.7
CP	18.1 ^a	20.3 ^b	17.4 ^a	17.7 ^a	0.6
Composition end					
NDF	67.0 ^c	69.8 ^c	69.2 ^c	71.4 ^c	2.4
ADF	44.3 ^c	46.5 ^c	45.6 ^c	44.5 ^c	1.7
CP	12.8 ^c	12.4 ^c	12.5 ^c	11.9 ^c	0.6

^{a,b,c}Least squares means in a row or for each nutrient within a column with different superscripts differ ($P < .01$).

TABLE 4. AVERAGE COMPOSITION OF BEGINNING AND END OF EXTRUSA SAMPLES (OM BASIS) FOR Paddock 1 FROM Cows Grazing Tall Fescue-Red Clover and Tall Fescue Alfalfa over time (N = 6)

Item	Period				SEM
	1	2	3	4	
Tall Fescue-Red Clover	-----	%		-----	
NDF	65.7 ^a	65.8 ^a	62.8 ^a	66.4 ^a	2.4
ADF	39.9 ^a	38.7 ^a	39.7 ^a	38.0 ^a	1.7
CP	12.8 ^a	13.5 ^a	13.9 ^a	13.4 ^a	0.6
Tall Fescue-Alfalfa					
NDF	50.1 ^{bc}	47.9 ^b	55.1 ^{cd}	60.2 ^d	2.4
ADF	36.4 ^a	36.4 ^a	40.1 ^a	41.0 ^a	1.7
CP	18.1 ^b	19.1 ^b	16.1 ^c	16.2 ^c	0.6

^{a,b,c}Least squares means in a row or within a column with different superscripts differ (P < .05).

TABLE 5. MEAN QUANTITY OF AVAILABLE FORAGE (OM BASIS) FOR BEGINNING AND END OF GRAZING Paddock 1 FOR Tall Fescue-Red Clover and Tall Fescue-Alfalfa over time (N = 18)^f

Item	Rotation			SEM
	1	2	3	
Tall Fescue-Red Clover	-----	kg/ha		-----
Beginning	3020.5 ^a	1994.5 ^b	1833.7 ^c	36.7
End	1809.3 ^a	1387.9 ^b	1373.7 ^b	36.7
Tall Fescue-Alfalfa				
Beginning	2810.8 ^d	2234.7 ^e	1784.9 ^c	36.7
End	1442.9 ^d	1304.5 ^b	1263.8 ^e	36.7

^{a,b,c,d,e}Least squares means in a row or for beginning and end within a column with different superscripts differ (P < .05).

^fTreatment × rotation × beginning and end interaction (quadratic, P = .03).

LIMIT FEEDING WHOLE OR CRACKED CORN-HAY DIETS COMPARED TO AN AD LIBITUM HAY DIET FOR BEEF COWS

K. E. Tjardes, D. B. Faulkner, J. W. Castree and D. D. Buskirk

SUMMARY

One hundred forty-five Angus x Simmental crossbred cows (596 ± 28 kg) with Simmental sired calves (38.5 ± 2.2 kg) were used to evaluate the performance of cows fed limited and ad libitum diets. The three treatments: ad libitum hay (16 kg/d), limited whole corn (6.1 kg/d) with hay (4.5 kg/d), and limited cracked corn (6.1 kg/d) with hay (4.5 kg/d) were evaluated over two years. Cow-calf pairs were blocked by calving date and randomly assigned to treatment. The cow-calf pairs were fed treatment diets starting 24 h after parturition until the beginning of breeding (62 ± 13 d). Intake was reduced ($P < .01$) for the limit fed treatments as expected. There was no difference in weight loss ($P > .10$) between the cows that were limit fed when compared to cows fed ad libitum hay. In addition, there was no difference ($P > .10$) in weight loss for the cows fed whole corn compared to cracked corn. Pregnancy rate was not influenced ($P > .10$) by treatment. Calf gain tended ($P = .09$) to be reduced by limit feeding. However, there was no significant difference in the subsequent cow-calf performance between the three treatments. Cows in early lactation can be limit fed corn-hay diets with no significant effect on performance.

INTRODUCTION

Limit feeding as an alternative feeding strategy has the potential benefits of reducing the feed cost per unit of gain, lowering the inputs of feed, and resulting in less feed wastage (Lake, 1986). Limit feeding has also been reported to cause an increase in feed efficiency of beef cattle (Hicks et al., 1990). Feed cost attributes to over 50% of the cost of producing cattle, therefore limit feeding has the potential to drastically reduce cow maintenance costs. Limit feeding of grain with a small amount of roughage (usually at least 0.5% of body weight) to beef cows is one alternative feeding strategy. These high concentrate diets are fed at a reduced dry matter intake to enable similar average daily gain as cattle fed ad libitum intake of roughage based diets (Loerch, 1990). Corn is a readily available, high energy feedstuff for midwest producers that is often relatively inexpensive. The objectives of this study were to evaluate a limit fed corn-hay diet compared to an ad libitum hay diet, and to determine if it is necessary to process the corn that is used in the limit fed cow diet.

PROCEDURE

One hundred forty-five Angus x Simmental crossbred cows (596 ± 28 kg) with Simmental sired calves (38.5 ± 2.2 kg) were utilized to evaluate the performance of cows fed limited and ad libitum diets. The three treatments: ad libitum hay (16 kg/d), limited whole corn (6.1 kg/d) with hay (4.5 kg/d), and limited cracked corn (6.1 kg/d) with hay (4.5 kg/d) were evaluated over two years with three replications per

treatment. The diets were formulated to supply similar amounts of energy based on a predicted intake of 15.9 kg for cows on the hay diet. All other nutrients met or exceeded National Research Council recommendations. Cow-calf pairs were blocked by calving date and randomly assigned to treatment. The cow-calf pairs were fed treatment diets starting 24 h after parturition until the beginning of breeding (62 ± 13 d). Initial cow weights were taken within 24 h of calving prior to feeding. Calf birth weights were used as initial weights. Final weights were taken after cows had been fed a common diet for three days and removed from feed and water for 16 h to reduce fill differences. Hay fed and refused was weighed and sampled for dry matter determination. Cow gain, cow condition change, calf gain, subsequent cow conception, and subsequent cow and calf performance were evaluated. Over the two year period, four cow-calf pairs were removed from the study for reasons unrelated to treatment.

Data were analyzed using the GLM procedure of SAS (1990), with pen as the experimental unit. Orthogonal contrasts were used to compare hay versus limited corn-hay treatments and whole versus cracked corn.

RESULTS

There was no difference in weight loss ($P > .10$) for cows on the limit fed corn-hay diet when compared to cows on ad libitum hay diet (table 1). There was no difference ($P > .10$) in the loss of weight of the cows between the whole corn and the cracked corn treatments. In addition, there was no difference ($P > .10$) in cow body condition score change.

Subsequent cow performance from the end of the study to weaning, cows tended ($P = .14$) to lose less weight when they had previously received the whole corn-hay diet when compared to the cracked corn hay diet. However there was no difference ($P > .10$) between weight loss of the limit fed and the ad libitum diets. In contrast, cows tended ($P = .14$) to lose less body condition when they previously consumed ad libitum hay compared to limit fed corn-hay. These results are inconsistent and are probably due to random chance. There was no difference ($P > .10$) in subsequent cow body condition change between the corn treatments. Pregnancy was not influenced ($P > .10$) by previous treatment. These results suggest that all the treatments resulted in cow performance that was adequate for good reproductive success.

Calf gain tended ($P = .09$) to be reduced by limit feeding, and the calves on the cracked corn treatment tended ($P = .13$) to gain better than those on the whole corn treatment. There was no difference ($P > .10$) observed in calf performance from the end of the treatment until weaning. Therefore, the diets that the cows received during the treatment period had little influence on overall calf performance.

CONCLUSIONS

Cows in early lactation can be limit fed a corn-hay diet with no significant effect on performance. Cow performance is not affected by processing the corn. Although, there was a tendency for the calves to perform better on the ad libitum hay and the limit fed cracked corn-hay diets, there was no difference in the subsequent performance of the calves due to the treatments.

LITERATURE CITED

- Hicks, R. B., F. N. Owens, D. R. Gill, J. J. Martin, and C. A. Strasia. 1990. Effects of controlled feed intake on performance and carcass characteristics of feedlot steers and heifers. *J. Anim. Sci.* 68:233.
- Lake, R. P. 1986. Limit feeding high energy rations to growing cattle. *Proc. Feed Intake by Beef Cattle. Anim. Sci. Dept., Oklahoma State University.* p 305.
- Loerch, S. C. 1990. Effects of feeding growing cattle high-concentrate diets at a restricted intake on feedlot performance. *J. Anim. Sci.* 68:3086.
- SAS. 1990. *SAS/STAT Users's Guide.* SAS Inst., Cary, NC.

Table 1. LIMIT FED WHOLE CORN-HAY AND CRACKED CORN-HAY DIETS COMPARED TO AD LIBITUM HAY, AND WHOLE CORN COMPARED TO CRACKED CORN IN LIMIT FED DIETS.

	Treatments				P-value	
	Hay	WC ^a	CC ^b	SE	Hay vs. corn	WC vs. CC
Intake, kg/d	16.1	10.6	10.6	0.16	0.001	1.00
Init. cow wt, kg	595	593	602	8.13	0.81	0.44
Final cow wt, kg	580	563	582	7.59	0.44	0.11
Cow gain, kg/d	-0.29	-0.50	-0.38	0.08	0.16	0.30
Initial BCS ^c	6.19	6.17	6.22	0.07	1.00	0.44
BCS ^c change	-0.56	-0.55	-0.51	0.08	0.70	0.75
Init. calf wt, kg	38.7	37.7	39.1	0.80	0.75	0.23
Final calf wt, kg	112	104	103	5.10	0.21	0.88
Calf gain, kg/d	1.18	1.09	1.15	0.03	0.09	0.13
Subsequent performance						
Final cow wt, kg	563	557	565	7.88	0.84	0.48
Cow gain, kg/d	-0.12	-0.04	-0.12	0.03	0.36	0.14
Final calf wt, kg	231	227	230	5.12	0.76	0.65
Calf gain, kg/d	0.88	0.92	0.95	0.04	0.31	0.54
BCS ^c change	-0.06	-0.23	-0.20	0.08	0.14	0.83
Pregnancy, %	98.5	100	100	1.95	59.8	46.4

^a(WC) limit fed whole corn-hay

^b(CC) limit fed cracked corn-hay

^cBody condition score (1 to 9 scale)

SUBSEQUENT PRODUCTIVITY OF BEEF HEIFERS THAT RECEIVED CREEP FEED FOR 0, 28, 56, OR 84 DAYS BEFORE WEANING

D. D. Buskirk, D. B. Faulkner, and F. A. Ireland

SUMMARY

Ninety Angus × Hereford reciprocal cross cows and their heifer calves were used to evaluate the effects of length of time receiving creep feed on subsequent heifer fertility and milk production. Heifer calves (156 ± 16 d of age) were randomly assigned to receive creep feed for 0, 28, 56, or 84 d before weaning while nursing dams grazing endophyte-infected tall fescue pastures. All heifers were managed alike after the 84-d treatment period. Increasing the length of time receiving creep feed increased rate of gain by .33 kg when the heifers had access to creep for 84 d compared to controls (linear and quadratic, $P < .001$). Length of time receiving creep feed influenced both hip height (quadratic, $P < .05$) and fat thickness (linear and quadratic; $P < .05$) at weaning. The percentage of heifers that were determined to be pubertal before the breeding season was linearly increased ($P < .05$) by 30% as length of time receiving creep feed increased. There was no difference in pregnancy rate or in the percentage of heifers that calved to the AI due to treatment. Milk production, at 52 d postpartum, was depressed linearly ($P < .05$) as time receiving creep feed increased, but was not different at 102 and 151 d of lactation. No difference in weight of calves was observed at 52, 102, 151, or 214 d of age. This study demonstrates that allowing replacement heifers ad libitum access to creep feed increases weight gain to weaning thereby hastening puberty, but suppresses subsequent milk production.

INTRODUCTION

Creep feeding of beef calves is a common management practice used by cow-calf operators to increase weaning weights when producing feeder calves. Replacement heifers are routinely subjected to the same feeding practices as their feeder calf contemporaries until postweaning. For this reason, it is important to identify the subsequent effects of supplemental creep feeding on replacement heifer lifetime productivity. Heifers that experience faster preweaning growth often reach puberty at younger ages and have greater reproductive success during a restricted breeding season. However, ad libitum creep feeding of beef heifers before puberty has been shown to reduce lifetime calf weaning weights by impairing milk production. This depression in milk production has been avoided when heifers were allowed only a limited amount of creep feed. Data that characterize beef heifer preweaning nutritional regimens that promote physiological development necessary for maximum future productivity are limited. The objective of this study was to examine the effects of varying the length of time receiving creep feed on reproductive performance and subsequent milk production of beef heifers.

MATERIALS AND METHODS

Ninety Angus × Hereford reciprocal cross cows and their heifer calves were used to evaluate the effects of length of time receiving creep feed on subsequent heifer fertility and milk production. The study was conducted at the Dixon Springs Agricultural Center, Simpson, IL from July 17, 1991 to September 14, 1993. Heifer calves (156 ± 16 d of age) were randomly assigned to receive creep feed for 0, 28, 56, or 84 d before weaning. Groups of 22 or 23 cow-calf pairs were randomly assigned to one of four 10-ha endophyte-infected tall fescue pastures. Calves receiving creep had ad libitum access to creep feed for their respective times. The creep feed contained primarily corn as an energy source and corn cobs as a roughage source (Table 1). All heifers were managed alike in a single group after the 84-d treatment period. Postweaning nutrition until breeding consisted of ad libitum access to mixed grass hay and a supplement containing 85% cracked corn, 15% white salt, and .31 mg/kg monensin.

Heifer shrunk weights were taken after a 16 h withdraw from water on d-0, 28, 56, and 84 of the treatment period. Heifer shrunk weights were also taken at 13, 19, 25, and 31 mo of age. Fat thickness between the 12th and 13th ribs was measured using an ultrasound instrument at weaning, 13 and 19 mo of age. Hip height was measured to a point directly over the hook bones at weaning, 13, 19, and 31 mo of age. Pelvic area was obtained at 14, 19, and 27 mo of age. Body condition score (BCS) on a 1 to 9 scale was assigned at 25 and 31 mo of age.

Concentrations of progesterone were determined in samples of serum collected 10 d before and on the 1st d of estrous synchronization. Heifers were considered pubertal if one or both of the serum samples contained progesterone concentrations ≥ 1.5 ng/mL. Estrus was synchronized with Syncro-Mate-B® and heifers were artificially inseminated approximately 48 h after removal of the implants. Fourteen days following AI, all heifers were exposed to multiple bulls in their respective breeding groups for the remainder of the 60-d breeding season. Pregnancy was determined by palpation per rectum 162 d after AI and all non-pregnant heifers were removed from the study. Heifers grazed stockpiled tall fescue pastures with pre- and postcalving winter supplementation consisting of tall fescue hay and ground corn. Heifers were group-fed and supplemented at the same rate (2.5 kg/d ground corn).

At parturition, heifers were scored according to degree of calving difficulty. Calving date was used to estimate calving rate to the timed AI (283 ± 11 d from AI). Heifers grazed tall fescue, red clover pastures postpartum. Calves were weaned at 214 ± 19 d of age and weight and hip height were recorded. Milk production estimates were obtained at 52, 102 and 151 ± 19 d postpartum for heifers by calf weigh-suckle-weigh procedures. The three milk production estimates were averaged to yield an estimate of average daily milk production. Milk composition was determined at 143 ± 15 d postpartum for a subsample of heifers by using a milking machine to obtain milk samples.

Statistical Analysis. Data were analyzed by analysis of variance for a randomized design using the GLM procedures of SAS (1990) with individual animal as the experimental unit. Data were analyzed by least squares procedures for unequal subclass numbers. The model statement included the heifers' sire breed and length of time receiving creep as independent variables. Milk production and calf performance data were analyzed using calf age as a covariate. Treatment differences were evaluated using linear and quadratic orthogonal contrasts.

RESULTS

Increasing the length of time receiving creep feed increased rate of gain during the 84 d before weaning (linear and quadratic, $P < .001$) (Table 2). Daily gain was increased by .33 kg when the calves had access to creep for 84 d compared to controls. As a result, weaning weight of heifers receiving ad libitum creep feed for 84 d was 24.5 kg greater than those that received no creep feed. Steer contemporaries allotted to these same treatments gained 40 kg more when creep fed for 84 d compared to controls (Tarr et al., 1994). Increasing time receiving creep increased weaning weight due to differences in both skeletal growth as measured by hip height (quadratic, $P < .05$) and body composition as measured by fat thickness (linear and quadratic; $P < .05$). Advantages in weight (linear and quadratic, $P < .01$) and fat thickness (linear, $P < .01$) continued to 13 mo of age for those heifers that received creep for longer periods. There were no differences in weight, hip height or fat thickness at 19 mo of age due to creep treatment.

The percentage of heifers that were determined to be pubertal before the breeding season was linearly increased ($P < .05$) by 30% as length of time receiving creep feed increased (Table 3). The greater number of heifers exhibiting estrous cycles before breeding as length of time receiving creep increased was likely caused by the increased body weight of the heifers at that time. Though increasing time receiving creep feed increased the percentage of heifers reaching puberty before breeding, there was no difference in the percentage of heifers that were palpated as pregnant at 19 mo of age nor in the percentage that calved to the AI due to treatment. Calving ease and the percentage of heifers calving unassisted was not affected by treatment even though there was a tendency ($P = .10$) for a linear increase in pelvic area at 19 mo of age as time receiving creep increased. Treatment did not influence pelvic area as measured at 14, and 27 mo of age. Increased time on creep feed exhibited a carry over affect on the birth weight of the heifers' calves. Birth weight was increased by 2.9 kg (linear, $P < .05$) as length of time receiving creep increased (Table 4).

From about 3 months of age to puberty is an especially critical period in mammary development because the mammary gland is developing at a much faster rate compared with body growth. An increased plane of nutrition during this period has been shown to reduce mammary secretory tissue and subsequent lactation yields in dairy heifers. Milk production, at 52 d postpartum, was depressed linearly ($P < .05$)

as time receiving creep feed increased. Heifers which consumed creep feed for 84 d produced 22% less milk than non-creep fed heifers early in their lactation. Milk organic matter, fat, protein, solids-not-fat, and lactose were not affected by time receiving creep feed. Milk production measured at 102 and 151 d of lactation followed similar numerical trends as that of 52 d, however they were not significant. Milk production of the heifers was lower than previous reports for Angus and Angus-Hereford heifers. This was likely caused by the detrimental effects of endophyte-infected tall fescue that can suppress milk production of beef heifers by as much as 50%, and may not have allowed these heifers to fully express differences in milk production due to treatment. As a result of low milk production, calf growth was depressed. Although milk production was depressed by increasing time receiving creep, there was no affect on calf production. No difference in weight of calves was observed at 52, 102, 151, or 214 d of age due to treatment.

This study demonstrates that allowing replacement heifers ad libitum access to creep feed can increase their weight gain to weaning thereby hastening puberty. However, it also provides additional evidence that increasing gain during this critical period of mammary development may also be responsible for the detrimental effects upon subsequent milk production. In contrast, rapid postweaning gain also hastens puberty, yet has a beneficial effect on subsequent milk production (Buskirk et al., 1995). Therefore, replacement heifer management programs that promote moderate growth preweaning and accelerated growth from weaning to breeding may best achieve both maximal reproductive performance and milk production from beef females.

CONCLUSIONS

Creep feeding replacement beef heifers for up to 84 d will increase weight gain and may increase the number of heifers exhibiting estrous before breeding. However, this practice can be detrimental to subsequent milk production of these females. Cow-calf operators may benefit from improved heifer productivity by not creep feeding replacement heifers for long periods of time so that moderate growth rates are maintained until puberty.

LITERATURE CITED

- Buskirk, D. D., D. B. Faulkner, and F. A. Ireland. 1995. Increased postweaning gain of beef heifers enhances fertility and milk production. *J. Anim. Sci.* (In press).
- SAS. 1990. SAS/STAT[®] User's Guide (Version 6, 4th Ed.). SAS Inst. Inc., Cary, NC.
- Tarr, S. L., D. B. Faulkner, D. D. Buskirk, F. A. Ireland, D. F. Parrett, and L. L. Berger. 1994. The value of creep feeding during the last 84, 56, or 28 days prior to weaning on growth performance of nursing calves grazing endophyte-infected tall fescue. *J. Anim. Sci.* 72:1084.

TABLE 1. COMPOSITION AND INTAKE OF CREEP FEED^{ab}

Dietary component	% of DM			
Organic matter	90.50			
Crude protein	12.40			
Nonprotein nitrogen	1.43			
Fiber	12.44			
	Time receiving creep feed, d			
	0	28	56	84
Intake, kg/d				
0 - 28 d	-	-	-	4.3
29 - 56 d	-	-	2.8	4.6
57 - 84 d	-	1.1	1.9	1.8
0 - 84 d ^c	-	1.1	2.3	3.6

^aProvided by Central Soya, Decatur, IN.

^bMineral and vitamin composition of DM: (%) Ca = 2.00; P = .40; Mg = .17; (mg/kg) I = 1.27; K = 1.00; Fe = 103.04; Zn = 52.40; Mn = 91.01; Co = .25; Cu = 14.20; Se = .26; (IU/kg) Vitamin A = 6,606; Vitamin D = 1,101; Vitamin E = 33.

^cTotal creep intake divided by days of access to creep.

TABLE 2. GROWTH OF HEIFER CALVES AS INFLUENCED BY LENGTH OF TIME RECEIVING CREEP FEED

Item	n	Time receiving creep, d				P-values ^a	
		0	28	56	84	L	Q
Initial wt, kg	90	140.7 ± 6.0	132.6 ± 5.6	131.7 ± 5.4	137.6 ± 5.9	.64	.16
Wt gain, kg/d							
0 - 28 d	90	.64 ± .05	.77 ± .05	.71 ± .04	.91 ± .05	.001	.43
29 - 56 d	90	.33 ± .15	.15 ± .05	.64 ± .05	1.08 ± .06	.001	.001
57 - 84 d	89	.79 ± .07	.34 ± .07	.71 ± .06	.76 ± .07	.30	.001
0 - 84 d	89	.58 ± .04	.42 ± .04	.69 ± .04	.91 ± .04	.001	.001
Weight, kg							
Weaning	89	189.9 ± 7.7	167.8 ± 7.3	190.9 ± 7.1	214.4 ± 7.6	.001	.001
13 mo	88	261.4 ± 8.5	252.8 ± 8.2	255.7 ± 7.9	288.8 ± 8.4	.01	.01
19 mo	84	308.2 ± 8.2	299.6 ± 8.0	304.4 ± 8.0	317.7 ± 8.1	.27	.12
25 mo	52	368.4 ± 11.1	353.5 ± 11.2	360.0 ± 12.6	369.4 ± 12.3	.83	.23
31 mo	50	348.3 ± 12.9	344.7 ± 13.0	358.0 ± 14.5	357.0 ± 15.3	.46	.91
Hip height, cm							
Weaning	89	103.3 ± 1.1	101.1 ± 1.1	102.0 ± 1.1	103.9 ± 1.1	.52	.03
13 mo	88	111.9 ± 1.4	111.1 ± 1.3	109.6 ± 1.3	112.2 ± 1.4	.92	.15
19 mo	84	121.3 ± 1.0	119.4 ± .9	119.3 ± .9	119.8 ± .9	.20	.13
31 mo	50	123.9 ± 1.4	123.7 ± 1.4	123.7 ± 1.6	124.4 ± 1.7	.81	.73
Fat thickness, cm							
Weaning	89	.69 ± .04	.61 ± .04	.71 ± .76	.76 ± .04	.02	.03
13 mo	88	.63 ± .04	.63 ± .03	.68 ± .03	.73 ± .04	.01	.37
19 mo	83	.43 ± .03	.40 ± .03	.40 ± .03	.44 ± .03	.78	.15
Body condition score ^a							
25 mo	52	3.6 ± .2	3.3 ± .2	3.3 ± .2	3.7 ± .2	.85	.07
31 mo	50	3.3 ± .2	3.7 ± .2	3.8 ± .2	3.4 ± .2	.85	.04

^aProbability of observing a greater *F*-value for linear (L) and quadratic (Q) effects.^bTotal creep intake divided by days of access to creep.^c(1 to 9 scale).

TABLE 3. REPRODUCTIVE TRAITS OF HEIFERS AS INFLUENCED BY LENGTH OF TIME RECEIVING CREEP FEED

Item	n	Time receiving creep, d				<i>P</i> -values ^a	
		0	28	56	84	L	Q
Pubertal before breeding, %	86	42.4 ± 8.7	52.6 ± 9.3	48.7 ± 9.1	72.6 ± 8.9	.03	.45
Pregnant at 19 mo, %	84	78 ± 2	73 ± 12	86 ± 12	58 ± 12	.32	.27
Calving rate to AI, % ^b	57	17.6 ± 10.0	23.1 ± 11.4	20.0 ± 10.7	16.7 ± 11.9	.90	.69
Calving ease ^c	56	1.4 ± .2	1.6 ± .2	1.5 ± .2	1.4 ± .2	.91	.27
Unassisted calving, % ^d	56	74 ± 14	59 ± 13	57 ± 14	69 ± 15	.75	.29
Pelvic area, cm ²							
14 mo	84	142.2 ± 5.3	139.0 ± 5.2	140.9 ± 5.2	148.3 ± 5.2	.30	.24
19 mo	84	177.7 ± 7.2	182.7 ± 7.0	189.1 ± 7.0	190.4 ± 7.1	.10	.76
27 mo	46	278.4 ± 13.2	265.2 ± 12.9	283.1 ± 16.5	269.7 ± 15.1	.87	.99

^aProbability of observing a greater *F*-value for linear (L) and quadratic (Q) effects.

^bCalculated as the percentage of heifers that calved 283 ± 11 d following AI of those heifers that calved.

^c1 to 5 scale.

^dPercentage of heifers with calving ease of 1.

TABLE 4. MILK PRODUCTION AND CALF GROWTH AS INFLUENCED BY LENGTH OF TIME RECEIVING CREEP FEED

Item	n	Time receiving creep, d				P-values*	
		0	28	56	84	L	Q
Milk production, kg/d							
52-d	50	3.7 ± .3	3.8 ± .3	3.4 ± .3	2.9 ± .3	.05	.28
102-d	50	3.0 ± .3	3.0 ± .3	2.6 ± .3	3.2 ± .3	.86	.40
151-d	50	2.3 ± .2	1.7 ± .3	1.9 ± .3	1.9 ± .3	.35	.35
Mean	51	3.0 ± .2	2.9 ± .2	2.7 ± .2	2.6 ± .2	.19	.80
Milk composition, %							
Organic matter	20	11.1 ± .4	11.6 ± .4	10.2 ± .4	11.0 ± .4	.43	.72
Fat	20	3.7 ± .4	4.1 ± .4	3.1 ± .4	3.8 ± .4	.62	.70
Protein	20	3.2 ± .1	3.3 ± .1	3.1 ± .1	3.0 ± .1	.16	.45
Solids-not-fat	20	8.1 ± .1	8.3 ± .1	7.84 ± .1	8.0 ± .1	.28	.22
Lactose	20	4.2 ± .1	4.1 ± .1	4.1 ± .1	4.2 ± .1	.83	.57
Calf wt, kg							
Birth	57	30.7 ± .8	30.1 ± 1.0	31.6 ± .9	33.6 ± 1.0	.02	.18
52-d	51	50.6 ± 2.3	49.2 ± 2.9	49.3 ± 2.7	52.8 ± .29	.58	.36
102-d	51	75.8 ± 3.8	72.0 ± 4.6	70.9 ± 4.5	80.4 ± 4.7	.51	.13
151-d	51	103.8 ± 5.0	98.5 ± 6.2	96.8 ± 6.0	105.1 ± 6.3	.93	.25
214-d	50	138.2 ± 6.1	129.9 ± 7.6	129.5 ± 7.3	138.4 ± 8.0	.99	.24
214-d hip height, cm	50	96.6 ± 1.3	97.1 ± 1.6	95.7 ± 1.5	96.7 ± 1.7	.86	.87

*Probability of observing a greater F-value for linear (L) and quadratic (Q) effects.

THE EFFECTS OF BREED, AGE, LENGTH OF TIME, AND TECHNICIAN ON FREEZE BRANDING SUCCESS OF ANGUS AND ANGUS CROSSBRED HEIFERS

F. A. Ireland, D. D. Buskirk and D. B. Faulkner

SUMMARY

One hundred seventy-two Angus and Angus x Polled Hereford crossbred heifers ranging in age from 8 to 12 months were freeze branded by one of two technicians using dry ice and alcohol at one of four times (45, 55, 60 and 75 seconds). The objectives of this study were to evaluate the effects of breed, age, length of time, and technician on freeze branding success. Brands were scored as percentage scarred, satisfactory, marginal, unsatisfactory; and groups satisfactory and marginal were combined to give a percentage of brands scored as legible. As length of time increased, the percentage of brands scored satisfactory and legible decreased ($P < .001$). The percentage of brands scored unsatisfactory increased ($P < .001$) as time increased. There was an effect ($P < .05$) of technician on percentage satisfactory, unsatisfactory and legible brands.

INTRODUCTION

Due to the inconsistent results produced by various techniques (Ross and Massey, 1966; Smithson *et al*, 1970; Farrel, 1979) freeze branding of farm animals has not been widely used as a means of permanent identification. However, when properly performed, freeze branding results in white hair growth which is highly visible at a distance and does not damage the hide of the animal.

Recent research (Ireland *et al*, 1994) has identified factors which influence the success of freeze branding cattle, however, the range of times may not have been long enough to evaluate the effects of over branding. The objectives of this study were to evaluate the effects of breed, age, technician and length of time on freeze branding results using dry ice and alcohol as coolants for freeze branding Angus and Angus x Polled Hereford crossbred heifers. The length of times evaluated have been increased over previous studies (Ireland *et al*, 1994) to better characterize the range of times producing satisfactory results.

MATERIALS AND METHODS

One hundred seventy-two Angus and Angus x Polled Hereford crossbred heifers were freeze branded using one of four times (45, 55, 60 and 75 seconds) by one of two experienced technicians. A slurry of dry ice and methyl alcohol was prepared in a styrofoam cooler by adding chunks of dry ice to methyl alcohol of sufficient quantity to extend approximately one inch above the freeze branding digit. The branding irons were allowed to remain in the liquid until the vigorous bubbling ceased, indicating the irons had reached the temperature of the liquid. The branding irons were four-inch numerals and letters manufactured by L & H Manufacturing and purchased through

Nasco, Fort Atkinson, Wisconsin. The animals were restrained in a livestock chute and the left hip of the animal was clipped using a large animal clipper (Oster®, Model 150) and surgical blades (Oster®, EA1-SUR) to allow sufficient space to apply four in-line digits. Dirt and debris were removed by brushing and the area was sprayed with methyl alcohol immediately prior to applying each iron. Age, breed, time of application and technician were recorded for each animal. Heifers were branded in November 1993 and February 1994 at the Dixon Springs Agricultural Center, University of Illinois.

Brands were evaluated in July and October 1994 after the animals' hair had changed color. Each digit was evaluated without clipping and placed in one of four categories: satisfactory, marginally satisfactory, unsatisfactory (lack of pigmentation change) and those resulting in the loss of hair were scored as scarred. For the purpose of evaluation, satisfactory and marginally satisfactory categories were combined to form a category labeled legible.

Variables were evaluated statistically by analysis of variance with the GLM procedure of SAS (1982). The model statement included scarred, satisfactory, marginal, unsatisfactory and legible (satisfactory + marginal) as dependent variables. Technician, breed (Angus vs crossbred) age, time, and the two way interactions were included as independent variables. Time iron was applied was analyzed as linear and quadratic orthogonal contrasts.

RESULTS AND DISCUSSION

In this trial, technician, breed, age, time and the two way interactions were included as independent variables. All interactions and main effects except for time and technician were non-significant ($P > .15$) and were removed from the model. This is in contrast to previous trials (Ireland *et al*, 1994) where there was a significant breed x time interaction.

There was a significant linear effect of time on the percentage of brands scored satisfactory, unsatisfactory, and legible (Table 1). As time increased from 45 to 75 seconds, the percentage of the brands scored as satisfactory (80.3 to 35.1, $P < .001$) and legible (96.7 to 61.0, $P < .001$) both declined. The percentage of brands scored unsatisfactory increased (3.3 to 37.3, $P < .001$) over the same range of times. While there was a numerical increase in the incidence of scarring at 75 seconds, there was no significant statistical difference ($P > .30$). The combination of decreased percentage satisfactory and legible and the increased percentage unsatisfactory clearly indicate that 75 seconds did not produce satisfactory results.

The percentage legible at 45, 55 and 60 seconds are all within an acceptable range with 45 seconds producing the most brands scored as satisfactory and legible. Previous trials (Ireland *et al*, 1994) have indicated little difference between branding times from 40 to 60 seconds on weanling and yearling heifers when using dry ice and

alcohol as cooling agents. The most consistent satisfactory results have been obtained with times between 40 and 50 seconds when following these techniques on weanling and yearling heifers.

Technician was a significant source of variation for brands scored satisfactory, unsatisfactory and legible ($P < .05$). This is in agreement with a previous trial (Ireland *et al*, 1994) where technician was a source of variation. The percentage of legible brands are higher for both technicians than in previous trials. This may be a result of increased experience freeze branding cattle.

CONCLUSIONS

The results of this trial indicate that as time is increased above 45 seconds the percentage satisfactory and legible brands decrease. Previous work has indicated that satisfactory results have been obtained with times from 40 to 60 seconds. The data suggests that 45 to 50 seconds may be an optimal length of time on weanling and yearling Angus and Angus x Hereford crossbred heifers freeze branded using dry ice and alcohol.

The experience of the technician may also have an effect on the success rate. With practice, satisfactory freeze brands can be produced using the technique described.

REFERENCES

- Farrell, R. K. 1979. A universal system for positive, unalterable identification of horses. *Norden News*, pp. 14-18.
- Ireland, F. A., D. D. Buskirk and D. B. Faulkner. 1994. Factors influencing freeze branding success of Angus and Angus x Hereford crossbred heifers. *Beef Research Report 1994*. pp 62-67. University of Illinois, Urbana.
- Ross, J. E. and J. W. Massey. 1966. Freeze branding cattle. *MU Guide 12/66* 7M:2201-2202. University of Missouri, Columbia, MO.
- SAS. 1982 SAS user's guide: Statistics. SAS Inst. Inc., Cary, NC.
- Smithson, L. J., H. W. Essig, C. B. Shawver, L. H. Boyd and B. Baker, Jr. 1970. Freeze branding of beef cattle, horses and swine. Information Sheet 1095, Mississippi State University.

**TABLE 1. BRANDING SCORES AS INFLUENCED BY APPLICATION TIME OF
FREEZE BRANDING IRON^a**

Brand score ^b	Time, seconds				P-value ^c
	45	55	60	75	
Number of heifers	55	34	48	35	
Scarred, %	0.0 ± 1.0	0.9 ± 1.0	0.0 ± 0.8	1.7 ± 1.0	.30
Satisfactory, %	80.3 ± 6.7	52.6 ± 6.9	64.8 ± 6.1	35.1 ± 6.9	.001
Marginal, %	16.4 ± 5.0	30.3 ± 5.2	20.3 ± 4.6	25.9 ± 5.2	.34
Unsatisfactory, %	3.3 ± 5.1	16.2 ± 5.4	15.0 ± 4.7	37.3 ± 5.3	.001
Legible, %	96.7 ± 5.2	82.9 ± 5.4	85.0 ± 4.8	61.0 ± 5.3	.001

^aLS Means ± SE

^bScarred = visible scarring; Satisfactory = very legible; Marginal = poor but legible; Unsatisfactory = not legible due to lack of pigmentation change; Legible = Satisfactory + Marginal.

^cProbability of observing a greater F-value for a linear effect of time.

EFFECTS OF SUPPLEMENTATION OF GRAZING STEERS WITH PROTEIN AND ENERGY ON BODY WEIGHT GAINS AND CARCASS COMPOSITION

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SUMMARY

This experiment was designed to assess the effects of different levels of protein and energy supplementation on body weight gains in steers grazing of tall fescue in the spring, and the carry over effects in the finishing phase. A total of 168 Angus steers (mean weight: 543.6 ± 6.13 lbs) were assigned to 6 treatments with 4 replicates (7 steers each) in a factorial design. Steers grazed the spring growth of tall fescue (T_1) were supplemented with 3.1 lb of ground corn grain (GC, T_2), or 3.1 lb of corn gluten feed (CGF, T_3), or 6.2 lb of GC (T_4), or 6.2 lb of CGF (T_5), or 1.5 lb of corn starch and 1.5 lb of corn gluten meal (T_6). Contrast for average daily gains between T_1 (1.40 lb/day) and the others (mean: 1.63 lb/day) was significant ($P < .035$) as well as ($P < .032$) when comparing CGF (T_5 , 1.82 lb/day) and GC (T_4 , 1.55 lb/day). Supplementation during the grazing period had no effect on performance during the finishing phase (mean: 2.78 lb/day) although it tended to increase ($P = .053$) ribeye area (T_1 : 11.01 in²; supplemented: 11.4 in²) as well as dressing percentage ($P = .068$; T_1 : 58.2, supplemented: 59.3). Supplementation during the grazing period increased body weight gains but responses seems to depend on the level and type of supplement. Corn gluten feed may be an useful supplement for animals grazing the spring growth of tall fescue especially if the level of supplementation is high. Different treatments during the grazing period had no effect on performance during the finishing period although tended to increase ribeye area and dressing percentage.

INTRODUCTION

Animal performance as well as the capacity of grazed forage to provide the nutrients to meet requirements has been poorly studied. Moreover, the responses to energy or protein supplementation or both protein and energy in animals grazing tall fescue is largely unknown.

Corn grain (GC) is commonly used as an energy supplement. However, corn gluten feed (CGF) has a high digestibility as well as high fiber content which may avoid reduction in forage fiber digestion commonly associated with GC. This effect may depend on the level of supplementation. In this study we wanted to evaluate the level (high or low), the source of energy (GC or CGF) as well as the amount of protein they can provide to the animal. It is also important to know if there is an additional response to protein supplementation (with corn gluten meal, CGM) for a given level of energy.

Different types of supplements may influence gain not only during the grazing period, but also when steers are taken from the pasture and fed a finishing diet. We also wanted to asses if energy or protein supplementation in stocker steers could have carry over effects on the performance in the finishing phase and on final carcass composition.

PROCEDURES

The grazing experiment was carried at Dixon Springs Agricultural Center between 4/6/88 and 6/29/88. A total of 168 Angus steers (mean weight = 543.6 ± 6.13 lbs) were assigned to 6 treatments with 4 replicates (7 steers/ replicate) during an 85 day period. Supplement treatments were arranged to provide different combinations of protein and energy. The amount of energy for given level and type of supplement was calculated from the metabolizable energy content of each supplement and the amount offered. The amount of ruminal escape protein (EP) of each supplement was calculated according to the amount offered, the crude protein content and, its ruminal degradability (NRC, 1985). The percentage of EP was 64, 32 and 60 for GC, CGF, and CGM respectively. For CS the amount of crude protein was negligible (0.3 %). Treatments were arranged to supply different amounts and combinations of ME and EP (Table 1).

Table 1. Amount of supplements, energy and ruminal escape protein offered in each treatment.

TREATMENT	ENERGY LEVEL	RUMINAL ESCAPE PROTEIN
	(Mcal ME/an/d)	(lb/an/d)
T ₁ : No supplement (P)	-	-
T ₂ : P + 3.1 lb GC	4.55 (L)	0.2 (L)
T ₃ : P + 3.1 lb CGF	4.2 (L)	0.2 (L)
T ₄ : P + 6.2 lb GC	9.1 (H)	0.4 (H)
T ₅ : P + 6.2 lb CGF	8.4 (H)	0.4 (H)
T ₆ : P + 1.5 lb CS + 0.7 lb CGM	4.4 (L)	0.4 (H)

ME: metabolizable energy; L and H: low and high level respectively. GC: ground corn; CGF: corn gluten feed; CS: corn starch; CGM: corn gluten meal.

Animals grazed the first growth of tall fescue pastures rotationally and supplements were given once a day in the morning. Steers were weighed during 2 consecutive days at the beginning and end of the experiment with 16 h of water and feed deprivation before weighing. After the grazing experiment was finished, steers were fed a fattening diet (130 days) in order to determine the carry over effects of previous supplementation. Final

weight of the grazing period were used as initial weights of the finishing period. At the end of the fattening phase, steers were weighted using the same procedures as in grazing period. Steers were slaughtered (11/11/88) and evaluated for hot carcass weight, yield grade, dressing, ribeye area, backfat thickness, marbling score, and quality grade. The experiment was analyzed as a factorial design using GLM procedures of SAS with pen as the experimental unit. Orthogonal contrasts were level of energy (L vs. H), type of energy (GC vs. CGF) and level of undegraded protein (L or H) at the L level of energy.

RESULTS

The effects of different treatments on the body weight gains during the grazing period are shown in Table 2.

Table 2. Body weights and performance in grazing steers supplemented with energy and

	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	SEM
Initial weight (lb)	545.5	544.7	542.4	547.2	541.4	540.3	1.25
Final weight (lb)	664.8	688.7	671.8	679.4	696.2	672.8	3.35
ADG (lb)	1.40	1.69	1.52	1.55	1.82	1.56	0.04

BWG: body weight gain, ADG: average daily gain. T₁: pasture only; T₂: pasture + 3.1 lb corn grain (GC); T₃: pasture + 3.1 lb corn gluten feed (CGF); T₄: pasture + 6.2 lb GC; T₅: pasture + 6.2 lb CGF; T₆: pasture + 1.5 lb corn starch and 1.5 lb corn gluten meal, SEM: standard error mean.

Supplemented animals tended to have a higher final weight (681.8 lb) than controls (664.8 lb, $P = .073$). Contrasts for final weights were also significant ($P < .048$) for CGF vs GC at the high level of supplementation (T₅ vs T₄).

Contrasts for ADG among treatments were significant ($P < .035$) for supplemented (mean: 1.62 lb/day) vs. no supplemented (1.4 lb/day). Considering both levels of supplementation GC was not different from CGF (T₂ and T₄ vs T₃ and T₅, $P > .05$). At the low level of supplementation, GC and CGF had a similar effect ($P > .05$). However, CGF had higher ADG ($P < .032$) than GC at the high level of supplementation (T₅ vs T₄).

Supplementation during the grazing period did not affect body weight gains during the finishing phase (Table 3). For carcass composition only the ribeye area (supplemented: 11.4, T₁: 11.01) and dressing percentage (supplemented: 59.3; T₁: 58.2) tended to be higher ($P = .053$ and $P = .068$, respectively) in the supplemented animals during the grazing period.

Table 3. Carry over effects of the supplementation during the grazing period on steer performance in the fattening phase and final carcass composition.

	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆	SEM
Final weight (lb)	1026	1050	1025	1047	1045	1039	25.9
Average daily gain (lb)	2.80	2.80	2.73	2.84	2.67	2.82	0.17
Hot carcass weight(lb)	597.7	625.1	602.1	618.9	628.6	611.2	20.6
Yield grade	3.05	2.88	2.83	2.9	3.05	2.85	0.24
Dressing (%)	58.2	59.5	58.8	59.1	60.2	58.8	0.96
Ribeye area (in ²)	11.01	11.6	11.3	11.5	11.5	11.1	0.34
Backfat thickness (in)	0.56	0.53	0.51	0.53	0.56	0.58	0.07
Marbling score *	1230	1240	1196	1260	1230	1240	82

* Marbling score: 1000 = choice⁻; 1100 = choice⁰; 1200 = choice⁺.

CONCLUSIONS

Supplementation of steers grazing the spring growth of tall fescue increased body weight gains but the response depended on the level and type of supplement. Corn grain showed a similar response than corn gluten feed at the low level (3 lb/d), but if the level of supplementation is high (6 lb/d) corn gluten feed was better. None of the diets during the grazing period affected animal performance during the finishing phase but supplementation during the grazing period tended to produce a higher rib eye area and dressing percentage.

ALKALINE HYDROGEN PEROXIDE-TREATED CANOLA SEED FOR RUMINANTS

1. DIGESTION OF LONG-CHAIN FATTY ACIDS

H. S. Hussein, N. R. Merchen, and G. C. Fahey, Jr.

SUMMARY

The objective was to evaluate the effectiveness of alkaline hydrogen peroxide treatment of whole canola seed (CS) as a means of weakening the seed coat while, at the same time, protecting unsaturated long-chain fatty acids (LCFA) from ruminal biohydrogenation without hindering their digestion in the lower gut. Six ruminally- and duodenally-cannulated beef steers were offered six isonitrogenous diets ad libitum twice daily in a 6×6 Latin square design. Treatments were arranged as a 2×3 factorial with two forage levels (70 vs 30% of dietary DM as corn silage) and three forms of CS supplementation including no CS or CS added at 10% of dietary DM as whole treated or untreated crushed. Canola seed contributed 5% added fat to the total diet. Feeding whole treated CS was superior to feeding crushed untreated CS in increasing the amounts of $C_{18:1}$, $C_{18:2}$, and $C_{18:3}$ flowing to the duodenum and the amounts disappearing postruminally. Results suggest that chemically treated whole CS can be used as a means of postruminal delivery of digestible unsaturated LCFA, especially $C_{18:1}$, which contributes 59% of the total fatty acids in CS. Results also suggest that whole-treated CS may be more beneficial when fed with low versus high forage diets.

INTRODUCTION

Ruminant adipose tissue and milk fat differ in their fatty acid (FA) composition from the diet (Moore and Christie, 1984) because of the biohydrogenation process occurring in the rumen. On average, the FA profiles (percentage of total FA) of ruminant adipose tissue (Wood, 1984) and milk fat (Grummer, 1991) are 38, 59, and 3% and 70, 25, and 5% for saturated, monounsaturated, and polyunsaturated FA, respectively. Because of recent concerns regarding the FA composition of dietary fat for humans and associated health problems attributed to fat intake, altering the FA composition of ruminant carcass or milk fat becomes important. Clinical research indicated that $C_{18:1}$ has a hypocholesterolemic effect equivalent to that of $C_{18:2}$ in normolipidemic subjects (McDonald et al., 1989). Mattson and Grundy (1985) also reported that the decrease in high-density-lipoprotein cholesterol (that has an inverse relationship with incidence of coronary heart disease) was less frequent in subjects consuming diets containing high concentrations of $C_{18:1}$. Of all oil seeds, CS has a unique FA profile of which $C_{18:1}$ contributes about 59% of the total FA (Fly and Johnston, 1990). Altering FA composition of ruminant edible products to increase the proportion of $C_{18:1}$ seems possible if FA in CS are protected from ruminal biohydrogenation. Protection of LCFA in CS from ruminal biohydrogenation has been achieved by several processes including Ca salt formation (Ferlay et al., 1993), emulsification and encapsulation in a matrix of formaldehyde-treated protein (Ashes et al., 1992; Atwal et al., 1991), or Jet-Sploding® (Khorasani et al., 1991). Because of limitations associated with these processes, an alternative process has been developed. This process involves mild chemical treatment with sodium hydroxide and hydrogen peroxide followed by heat to weaken the seed coat of whole CS such that it will be protected from ruminal microbial biohydrogenation but be susceptible to enzymatic digestion in the small

intestine. The objective of this study was to evaluate under different dietary conditions the efficacy of the chemical treatment in protecting LCFA in CS from ruminal microbial biohydrogenation and to determine their availability for intestinal digestion.

MATERIALS AND METHODS

Animals and Diets: Six Angus \times Simmental steers (mean BW \pm SD = 354 \pm 18 kg) were used in this experiment. Steers were fitted with permanent ruminal and T-type duodenal cannulas. The experimental design was a 6 \times 6 Latin square with 18-d periods. The first 14 d were used for adaptation to the diet and the last 4 d were used for sample collection. Treatments were arranged as a 2 \times 3 factorial. The main effects were two dietary forage levels (high forage [HF] or low forage [LF] provided by corn silage at 70 or 30% of dietary DM) and three CS supplementations including no CS (NCS) or CS added at 10% of dietary DM as whole treated with alkaline hydrogen peroxide (WTCS) or crushed untreated (CUCS). The WTCS were prepared by mixing intact whole CS with an aqueous solution containing 5 to 10% (of DM weight of the CS) NaOH. This was followed by adding and mixing a solution of .5 to 2.5% H₂O₂ to the NaOH-treated CS. The CUCS were crushed through a roller mill to fracture the seed coat. Canola seed contributed 5% added FA to the diets containing CS. The ingredient and chemical compositions of the six experimental diets are presented in Table 1. Diets were isonitrogenous (13.2% CP on a DM basis) and contained equal concentrations of Ca, P, and S (.88, .44, and .21%, respectively). Diets were formulated to meet or exceed the nutrient requirements recommended by the NRC (1984) for steers weighing 354 kg and gaining 1.3 kg/d. Diets were offered ad libitum and were fed twice daily (0600 and 1800) in two equal portions. Chromic oxide was used as an indigestible marker to measure nutrient flow to the duodenum and fecal output.

Sample Collection and Preparation: Representative samples of dietary ingredients, total mixed diets, andorts were collected, dried (55°C), and ground (1 mm). Beginning at 0800 on d 15 of each period, samples of duodenal digesta and feces were collected from steers by following a sampling schedule that allowed a total of 18 samples (one sample for each 80 min of the day) to be collected from each steer over the 4-d sampling period. Duodenal samples were collected, composited for each steer, lyophilized and ground (1 mm). Fecal samples were collected by grab sampling, composited for each steer, dried (55°C), and ground (1 mm).

Analytical Procedures: Samples were analyzed for DM, OM, and Kjeldahl-N (AOAC, 1984). Samples were prepared for LCFA analysis as methyl esters (Sukhija and Palmquist, 1988) and concentrations of LCFA were determined using a Hewlett-Packard Model 5890A gas chromatograph (Hewlett Packard Co., Palo Alto, CA). Duodenal and fecal samples were prepared for Cr analysis according to the method of Williams et al. (1962) and concentrations of Cr were measured using an atomic absorption spectrophotometer (Model 2380, Perkin-Elmer Corp., Norwalk, CT).

Statistical Analyses: Data were analyzed as a Latin square design according to the GLM procedures of SAS (1985). Model sums of squares were separated into steer, period, and treatment effects. Because treatments were arranged as a 2 \times 3 factorial, the sums of squares for the treatments in the GLM model were further separated into dietary forage level, CS

supplementation, and the dietary forage level \times CS supplementation interaction. When significant ($P < .05$) interactions were detected, individual treatment means were compared by the LSD procedure (Fisher, 1949). When interactions were not detected ($P > .05$), means for the main effect that showed significant ($P < .05$) effects were compared with the same procedure (Fisher, 1949). Because of poor feed consumption for reasons unrelated to diet, data collected from the steer that was fed the diet containing HF and NCS in period three were eliminated before analysis. Therefore, tabulated values are least squares means.

RESULTS AND DISCUSSION

Diet Analyses: The LCFA composition of the experimental diets is presented in Table 2. Canola seed was added to supply 5% more fat in diets containing CS. Total LCFA concentrations were 3.2, 8.5, and 8.7% of DM in diets containing HF and 4.7, 9.7, and 9.9% in diets containing LF when supplemented with NCS, WTCS, or CUCS, respectively (Table 2). These concentrations indicate that 5.0 to 5.4% more FA was added and reflect the concentrations of LCFA in dietary ingredients (data not shown).

Intake and Duodenal Flow of LCFA: Although diets were fed ad libitum, dry matter intake (kilograms per day) was not affected ($P > .05$) by dietary forage level, CS supplementation, or their interaction and ranged between 8.2 and 10.6 kg/d (see carbohydrate data in this report). No interactions ($P > .05$) between dietary forage level and CS supplementation were observed for intakes of LCFA (Table 3). Steers fed diets containing LF had higher intakes of individual and total LCFA than steers fed diets containing HF (824.5 vs 592.3 g/d of total LCFA, respectively) and can be explained by the different concentrations of LCFA in ground corn and corn silage (data not shown). Steers fed diets containing CS (either WTCS or CUCS) had similar ($P > .05$) intakes of LCFA but higher LCFA intakes than steers fed diets containing NCS. When steers were fed diets containing NCS, WTCS, or CUCS, the intakes were 389.7, 903.8, and 831.6 g/d of total LCFA, respectively. Significant interactions between dietary forage level and CS supplementation were detected for flows (grams per day) of C_{18} unsaturated FA to the duodenum (Table 3). Flows of C_{18} unsaturated FA to the duodenum were highest for steers fed the diet containing LF and WTCS. This diet contributed 120.5, 65.7, and 17.5 g/d more (i.e., 60, 95, and 90% higher) $C_{18:1}$, $C_{18:2}$, and $C_{18:3}$ at the duodenum, respectively, when compared with the diet containing HF and WTCS. This observation suggests a greater extent of ruminal biohydrogenation of C_{18} unsaturated FA when WTCS was fed with HF and may be attributed to the longer retention time often associated with diets containing HF versus LF. Steers fed the diet containing LF and WTCS consumed 118.9, 111.4, and 12.6 g/d more $C_{18:1}$, $C_{18:2}$, and $C_{18:3}$, respectively, when compared with steers fed the diet containing HF and WTCS, reflecting the contribution of ground corn versus corn silage. The advantage of supplementing diets containing LF versus HF with WTCS in terms of delivering more C_{18} unsaturated FA to the small intestine of steers is perhaps an indication of greater breakdown of the fiber fraction in CS (i.e., the seed coat) when the basal diet contained HF. Flows of C_{18} unsaturated FA to the duodenum were lower for steers fed diets containing CUCS versus WTCS, indicating more extensive biohydrogenation of unsaturated FA due to greater accessibility in the CUCS to the ruminal microbes. Flows of $C_{18:1}$ and $C_{18:3}$ to the duodenum were similar ($P > .05$) for steers fed CUCS at either forage level but flow of $C_{18:2}$ was 52% higher for steers fed the diet containing LF and CUCS versus that containing HF and CUCS. Flows of C_{18} unsaturated FA

to the duodenum were lowest for steers fed diets containing NCS due to the lower FA intakes.

Ruminal Biohydrogenation of LCFA: The LCFA composition of duodenal digesta and calculated (Wu et al., 1991) values for ruminal biohydrogenation of unsaturated LCFA are presented in Table 4. Steers fed diets containing WTCS had the lowest proportions of $C_{18:0}$ and the highest proportions of all C_{18} unsaturated FA. Steers fed diets containing CUCS had the highest proportions of $C_{18:0}$ and much lower proportions of C_{18} unsaturated FA when compared with steers fed diets containing WTCS. These data indicate that feeding WTCS was effective in altering FA composition of duodenal digesta. Extents of apparent biohydrogenation of $C_{18:1}$ were similar ($P > .05$) for diets containing HF or LF. However, extents of apparent biohydrogenation of $C_{18:2}$, $C_{18:3}$, and total C_{18} unsaturated FA were higher for diets containing HF versus LF. Steers fed diets containing WTCS had much lower extents of apparent biohydrogenation of $C_{18:1}$ (38.4 vs. 62.3%), $C_{18:2}$ (64.7 vs 74.9%), $C_{18:3}$ (48.4 vs 75.0%), and total C_{18} unsaturated FA (49.0 vs. 68.0%) in the rumen than steers fed diets containing CUCS. It is clear that the extent of ruminal biohydrogenation of LCFA from CS was reduced when diets were supplemented with WTCS. Access to the LCFA in WTCS was partially denied to the ruminal microbes by the presence of the seed coat. Feeding WTCS with LF resulted in the lowest numerical values for extent of apparent biohydrogenation of individual and total C_{18} unsaturated FA.

Digestion of LCFA: With the exception of $C_{18:3}$, no interactions ($P > .05$) between dietary forage level and CS supplementation were observed for the amounts of LCFA disappearing postruminally (Table 5). Amounts of $C_{16:0}$ apparently digested postruminally were not affected ($P > .05$) by dietary forage level or CS supplementation. Steers fed the diet containing LF and WTCS had 50, 184, and 1691 % greater amounts of $C_{18:3}$ apparently digested postruminally when compared with steers fed diets containing HF and WTCS, CUCS, or NCS, respectively. Greater amounts of $C_{18:1}$ (109.1 vs 86.6 g/d) and $C_{18:2}$ (64.3 vs 40.4 g/d) were digested postruminally when steers were fed diets containing LF versus HF. Amounts of $C_{18:0}$, $C_{18:1}$, $C_{18:2}$, and total LCFA apparently digested postruminally were affected by CS supplementation. Steers fed diets containing NCS had the least amounts of $C_{18:0}$, $C_{18:1}$, $C_{18:2}$, and total LCFA apparently digested postruminally. The amounts of LCFA apparently digested postruminally when steers were fed diets containing WTCS were 26% less for $C_{18:0}$, 92% more for $C_{18:1}$, and 54% more for $C_{18:2}$ when compared with steers fed diets containing CUCS. However, similar ($P > .05$) amounts of total LCFA were apparently digested postruminally when steers were fed diets containing either WTCS or CUCS. The quantity of C_{18} unsaturated FA (especially $C_{18:1}$ which is about 62% of the LCFA in CS) digested postruminally is the most important measurement in evaluating the efficacy of treatment of CS in terms of making LCFA in CS available for digestion and absorption in the small intestine. Based on data in Table 5, it is clear that the chemical treatment of CS was successful in delivering greater amounts of digestible C_{18} unsaturated FA to the small intestine. Apparent postruminal digestibilities of LCFA as percentages of LCFA entering the small intestine are also presented in Table 5. Interactions between dietary forage level and CS supplementation were observed only for apparent postruminal digestibilities of $C_{18:0}$ and $C_{18:2}$. Steers fed the diet containing LF and WTCS had apparent postruminal digestibilities that were 27.7 and 10.9 percentage units lower for $C_{18:0}$ and $C_{18:2}$, respectively, when compared with the average values calculated when steers were fed the remaining diets containing supplemental fat, which did not differ ($P > .05$) in digestibilities of

C_{18:0} and C_{18:2}. The digestibilities of C_{18:0} (83.4 vs 54.7%) and C_{18:2} (74.5 vs 64.4%) also were depressed by replacing HF with LF in the diets containing WTCS. Steers fed diets containing HF had higher ($P < .05$) digestibilities of C_{16:0} (79.8 vs 63.3%), C_{18:1} (73.2 vs 64.2%), C_{18:3} (78.5 vs 70.0%), and total LCFA (82.6 vs 67.3%) when compared with steers fed diets containing LF. Apparent postruminal digestibilities of C_{18:1}, C_{18:3}, and total LCFA also were affected by CS supplementation. Apparent postruminal digestibilities were 81.1, 62.1, and 62.8% for C_{18:1}, 93.3, 63.1, and 66.5% for C_{18:3}, and 81.6, 67.3, and 76.0% for total LCFA when steers were fed diets containing NCS, WTCS, or CUCS, respectively. Steers fed diets containing NCS had the highest digestibilities and those fed either WTCS or CUCS had much lower digestibilities of C_{18:1} and C_{18:3}. Digestibilities of total LCFA in diets containing either NCS or CUCS were similar ($P > .05$) and were much higher than those observed for diets containing WTCS.

CONCLUSIONS

The alkaline hydrogen peroxide treatment of whole CS was successful in protecting unsaturated C₁₈ FA from ruminal microbial biohydrogenation and in making significant amounts of these FA (especially C_{18:1}) available for digestion and absorption in the small intestine. In addition, the treatment provided better ruminal protection and greater delivery of digestible unsaturated C₁₈ FA to the small intestine when WTCS was supplemented to diets containing LF versus HF. Because diets used for finishing beef or high-producing dairy cows are mostly LF, this may allow WTCS supplementation of LF diets to be used in an attempt to alter FA composition of the meat and milk. Meat and milk products that contain less saturated FA and more unsaturated C₁₈ FA (especially C_{18:1}) may be desirable to health-conscious consumers.

REFERENCES

- AOAC. 1984. Official Methods of Analysis (14th Ed.). Association of Official Analytical Chemists. Washington, DC.
- Ashes, J. R., P. St. Vincent Welch, S. K. Gulati, T. W. Scott, G. H. Brown, and S. Blakeley. 1992. Manipulation of the fatty acid composition of milk by feeding protected canola seeds. *J. Dairy Sci.* 75:1090.
- Atwal, A. S., M. Hidirolou, and J. K. G. Kramer. 1991. Effects of feeding Protec® and alpha-tocopherol on fatty acid composition and oxidative stability of cow's milk. *J. Dairy Sci.* 74:140.
- Ferlay, A., J. Chabrot, Y. Elmeddah, and M. Doreau. 1993. Ruminal lipid balance and intestinal digestion by dairy cows fed calcium salts of rapeseed oil fatty acids or rapeseed oil. *J. Anim. Sci.* 71:2237.
- Fisher, R. A. 1949. The Design of Experiments. Oliver and Boyd Ltd., Edinburgh, Scotland.

- Fly, A. D., and P. V. Johnston. 1990. Tissue fatty acid composition, prostaglandin synthesis, and antibody production in rats fed corn, soybean, or low erucic acid rapeseed oil (canola oil). *Nutr. Res.* 10:1299.
- Grummer, R. R. 1991. Effects of feed on the composition of milk fat. *J. Dairy Sci.* 74:3244.
- Khorasani, G. R., P. H. Robinson, G. de Boer, and J. J. Kennelly. 1991. Influence of canola fat on yield, fat percentage, fatty acid profile, and nitrogen fractions in Holstein milk. *J. Dairy Sci.* 74:1904.
- Mattson, F. H., and S. M. Grundy. 1985. Comparison of effects of dietary saturated, monounsaturated, and polyunsaturated fatty acids on plasma lipids and lipoproteins in man. *J. Lipid Res.* 26:194.
- McDonald, B. E., J. M. Gerrard, V. M. Bruce, and E. J. Corner. 1989. Comparison of the effect of canola oil and sunflower oil on plasma lipids and lipoproteins and on in vivo thromboxane A₂ and prostacyclin production in healthy young men. *Am. J. Clin. Nutr.* 50:1382.
- Moore, J. H., and W. W. Christie. 1984. Digestion, absorption and transport of fats in ruminants. Page 123 *in* *Fats in Animal Nutrition*. J. Wiseman, ed. Butterworths, London, England.
- NRC. 1984. *Nutrient Requirements of Beef Cattle* (6th Ed). National Academy Press, Washington, DC.
- SAS® User's Guide: Statistics, Version 5 Edition. 1985. SAS Inst. Inc., Cary, NC.
- Sukhija, P. S., and D. L. Palmquist. 1988. Rapid method for determination of total fatty acid content and composition of feedstuffs and feces. *J. Agric. Food Chem.* 36:1202.
- Williams, C. H., D. J. David, and O. Iismaa. 1962. The determination of chromic oxide in faeces samples by atomic absorption spectrophotometry. *J. Agric. Sci. (Camb.)* 59:381.
- Wood, J. D. 1984. Fat deposition and the quality of fat tissue in meat animals. Page 407 *in* *Fats in Animal Nutrition*. J. Wiseman, ed. Butterworths, London, England.
- Wu, Z., O. A. Ohajuruka, and D. L. Palmquist. 1991. Ruminal synthesis, biohydrogenation, and digestibility of fatty acids by dairy cows. *J. Dairy Sci.* 74:3025.

TABLE 1: INGREDIENT AND CHEMICAL COMPOSITION OF DIETS¹ FED TO STEERS

Item	HF			LF		
	NCS	WTCS	CUCS	NCS	WTCS	CUCS
----- (% of DM) -----						
Ingredient composition						
Corn silage	70.0	70.0	70.0	30.0	30.0	30.0
Canola meal	5.2	1.1	1.1	8.3	4.2	4.2
Canola seed	...	10.0	10.0	...	10.0	10.0
Ground corn	17.05	11.31	11.31	54.15	48.50	48.50
Cane molasses	4.32	4.15	4.19	4.78	4.60	4.60
Urea	.68	.85	.81	.22	.40	.40
Limestone	1.27	1.31	1.31	1.59	1.97	1.97
Dicalcium phosphate	.66	.56	.56	.52
Sodium sulfate	.49	.39	.39	.11
Trace mineralized salt ²	.30	.30	.30	.30	.30	.30
Vitamin premix ³	.03	.03	.03	.03	.03	.03
Chemical composition						
OM	92.3	92.3	92.7	94.0	93.5	94.1
CP	13.2	13.0	13.2	13.4	13.3	13.3

¹High (HF) or low (LF) forage diets containing no canola seed (NCS) or canola seed as whole treated (WTCS) or crushed untreated (CUCS).

²Composition (g/100 g): NaCl (97 to 99), Zn (> .35), Fe (> .2), Mn (> .18), Cu (> .035), I (> .01), Se (> .009), Co (> .006).

³Composition (per gram): vitamin A (3,300 IU), vitamin D₃ (330 IU), vitamin E (44 IU), vitamin K (2.2 mg), vitamin B₁₂ (.0176 mg), riboflavin (4.4 mg), D-pantothenic acid (12.1 mg), niacin (16.5 mg), choline chloride (165.0 mg).

TABLE 2: LONG-CHAIN FATTY ACID (LCFA) COMPOSITION OF DIETS¹ FED TO STEERS

LCFA	HF			LF		
	NCS	WTCS	CUCS	NCS	WTCS	CUCS
	----- (mg/g DM) -----					
C _{16:0}	5.6	8.1	8.1	7.1	9.4	9.2
C _{18:0}	.8	1.7	1.5	1.0	1.8	1.8
C _{18:1}	8.5	43.3	44.0	12.6	47.0	48.1
C _{18:2}	16.6	26.0	27.0	25.5	33.2	33.5
C _{18:3}	.6	5.6	5.9	.9	5.9	6.1
Total	32.1	84.7	86.5	47.1	97.3	98.7

¹High (HF) or low (LF) forage diets containing no canola seed (NCS) or canola seed as whole treated (WTCS) or crushed untreated (CUCS).

TABLE 3: LEAST SQUARES MEANS FOR LONG-CHAIN FATTY ACID (LCFA) INTAKE AND FLOWS OF LCFA TO THE DUODENUM OF STEERS FED DIETS¹ CONTAINING DIFFERENT FORAGE LEVELS AND DIFFERENT CANOLA SEED SUPPLEMENTATIONS

Item	HF			LF			Significance (<i>P</i> <)		
	NCS	WTCS	CUCS	NCS	WTCS	CUCS	SE	F	F × CS
LCFA intake	----- (g/d) -----								
C _{16:0}	55.7	74.8	66.2	70.7	100.6	90.3	6.1	.0001	.002 .60
C _{18:0}	8.1	15.3	12.9	9.8	19.4	16.9	1.1	.0006	.0001 .42
C _{18:1}	71.7	382.0	351.5	124.3	500.9	464.1	34.7	.002	.0001 .54
C _{18:2}	165.8	244.9	225.4	259.8	356.3	329.5	21.5	.0001	.0008 .91
C _{18:3}	4.7	50.4	47.6	8.8	63.0	58.7	4.5	.0111	.0001 .57
Total	305.9	767.4	703.6	473.5	1040.2	959.7	66.3	.0001	.0001 .66
LCFA flow to duodenum									
C _{16:0}	58.6	83.1	68.0	72.4	89.9	92.2	8.1	.03	.04 .49
C _{18:0}	141.8	348.7	384.4	204.1	401.8	469.3	25.9	.003	.0001 .78
C _{18:1}	46.6 ^d	199.9 ^b	119.4 ^c	76.5 ^d	320.4 ^a	140.7 ^c	18.4	.0005	.0001 .02
C _{18:2}	36.5 ^c	69.4 ^b	47.0 ^c	63.1 ^b	135.1 ^a	71.2 ^b	8.5	.0001	.0001 .03
C _{18:3}	.1 ^d	19.5 ^b	9.5 ^c	2.4 ^d	37.0 ^a	12.9 ^c	1.8	.0001	.0001 .0002
Total	283.5	720.6	628.3	418.5	984.2	786.3	47.7	.0001	.0001 .30

¹High (HF) or low (LF) forage (F) diets containing no canola seed (NCS) or canola seed (CS) as whole treated (WTCS) or crushed untreated (CUCS).

^{a,b,c,d}Means in the same row with different superscript letters differ (*P* < .05).

TABLE 4: LEAST SQUARES MEANS FOR LONG-CHAIN FATTY ACID (LCFA) COMPOSITION OF DUODENAL DIGESTA AND BIOHYDROGENATION OF UNSATURATED C₁₈ FATTY ACIDS IN THE RUMEN OF STEERS FED DIETS¹ CONTAINING DIFFERENT FORAGE LEVELS AND DIFFERENT CANOLA SEED SUPPLEMENTATIONS

LCFA	HF			LF			Significance (<i>P</i> <)			
	NCS	WTCS	CUCS	NCS	WTCS	CUCS	SE	F	CS	F × CS
Composition of duodenal digesta	----- (% of total LCFA) -----									
C _{16:0}	19.3	11.6	11.0	17.3	9.1	11.7	.8	.04	.0001	.06
C _{18:0}	50.2	48.5	61.8	49.6	41.1	59.9	2.2	.06	.0001	.20
C _{18:1}	17.5	27.5	18.6	17.8	32.4	17.6	1.8	.30	.0001	.16
C _{18:2}	12.6	9.7	7.2	14.8	13.7	9.2	1.3	.01	.0007	.66
C _{18:3}	.4 ^d	2.7 ^b	1.5 ^c	.6 ^d	3.8 ^a	1.7 ^c	.2	.001	.0001	.01
Biohydrogenation in the rumen ²	----- (% of intake) -----									
C _{18:1}	29.8	43.6	61.9	30.6	33.2	62.8	5.0	.45	.0001	.37
C _{18:2}	75.7	69.1	77.3	72.3	60.4	72.4	2.6	.009	.0005	.53
C _{18:3}	78.1	58.1	77.7	68.6	38.6	72.2	3.6	.0004	.0001	.11
Total unsaturated C ₁₈	60.9	53.9	68.8	59.0	44.1	67.1	2.8	.05	.0001	.20

¹High (HF) or low (LF) forage (F) diets containing no canola seed (NCS) or canola seed (CS) as whole treated (WTCS) or crushed untreated (CUCS).

²Calculated according to the equation of Wu et al. (1991).

^{a,b,c,d}Means in the same row with different superscript letters differ (*P* < .05).

TABLE 5: LEAST SQUARES MEANS FOR APPARENT POSTRUMINAL DIGESTION OF LONG-CHAIN FATTY ACIDS (LCFA) IN STEERS FED DIETS¹ CONTAINING DIFFERENT FORAGE LEVELS AND DIFFERENT CANOLA SEED SUPPLEMENTATIONS

Apparent postruminal digestion of LCFA	HF			LF			Significance (<i>P</i> <)		
	NCS	WTCS	CUCS	NCS	WTCS	CUCS	SE	F	F × CS
	----- (g/d) -----								
C _{16:0}	51.8	65.3	51.5	54.2	53.4	57.5	9.2	.87	.73
C _{18:0}	145.2	290.1	320.0	132.5	220.7	371.8	28.8	.64	.0001
C _{18:1}	40.9	134.2	84.9	61.7	184.7	81.0	14.2	.05	.0001
C _{18:2}	31.6	51.9	37.6	55.3	85.9	51.7	6.0	.0001	.0001
C _{18:3}	.1 ^d	13.7 ^b	7.0 ^c	2.2 ^d	20.6 ^a	7.5 ^c	1.3	.002	.0001
Total	269.7	555.2	501.0	305.9	565.2	569.5	47.8	.29	.0001
	----- (% entering the small intestine) -----								
C _{16:0}	86.9	78.7	73.8	74.6	52.7	62.8	6.7	.004	.06
C _{18:0}	95.4 ^a	83.4 ^{ab}	83.8 ^{ab}	64.9 ^c	54.7 ^c	79.9 ^b	5.5	.0001	.04
C _{18:1}	83.8	65.0	69.7	78.5	58.3	55.8	3.6	.003	.0001
C _{18:2}	85.0 ^{ab}	74.5 ^c	78.6 ^{bc}	88.2 ^a	64.4 ^d	72.9 ^c	2.4	.03	.0001
C _{18:3}	93.0	69.1	73.5	93.6	57.1	59.4	4.3	.008	.0001
Total	90.7	77.1	80.0	72.5	57.5	71.9	3.8	.0001	.003

¹High (HF) or low (LF) forage (F) diets containing no canola seed (NCS) or canola seed (CS) as whole treated (WTCS) or crushed untreated (CUCS).

^{a,b,c,d}Means in the same row with different superscript letters differ (*P* < .05).

ALKALINE HYDROGEN PEROXIDE-TREATED CANOLA SEED FOR RUMINANTS

2. DIGESTION OF ORGANIC MATTER, CARBOHYDRATES, AND ENERGY

H. S. Hussein, N. R. Merchen, and G. C. Fahey, Jr.

SUMMARY

The objective was to determine the effects of fat supplementation on ruminal fermentation and postruminal digestion of OM, carbohydrates, and energy of diets containing different levels of forage. Six ruminally- and duodenally-cannulated beef steers (354 kg) were offered six isonitrogenous diets ad libitum twice daily in a 6×6 Latin square design. Treatments were arranged as a 2×3 factorial with two forage levels and three forms of fat supplementation. The forage levels were high (HF) or low forage (LF) provided by corn silage (70 vs 30% of dietary DM) and the three forms of fat supplementation (from canola seed [CS]) included no CS or CS added at 10% of dietary DM as whole treated (WTCS) with alkaline hydrogen peroxide or crushed untreated (CUCS). Fat from CS provided 5% of dietary DM. The remaining dietary ingredients were corn, canola meal, molasses, and urea. Fat supplementation did not affect ($P > .05$) dry matter intake (DMI). With few exceptions, fat supplementation did not affect ($P > .05$) ruminal, postruminal, or total tract digestibilities of OM, structural and nonstructural carbohydrates, and GE. Ruminal disappearance of GE was decreased ($P < .05$) when diets were supplemented with fat from WTCS, and total tract digestibilities of OM and GE were decreased ($P < .05$) when diets were supplemented with fat from CS in either form. Results suggest that fat supplementation (at 5% of dietary DM) in the form of WTCS or CUCS had no negative effects on ruminal fermentation of OM, carbohydrates, or energy when steers were offered diets containing HF or LF ad libitum.

INTRODUCTION

The use of supplemental fat to increase the energy density of ruminant diets is increasing rapidly. However, supplemental fat can affect ruminal digestion of carbohydrates negatively through an inhibitory effect of long-chain fatty acids (LCFA) on fiber digestion (Palmquist and Jenkins, 1980). Other researchers (Sutton et al., 1983; Zinn, 1989) indicated that fat supplementation was associated with a depression in carbohydrate fermentation, a reduction in ruminal fiber digestion, and a shift in the site of digestion from rumen to hindgut. Therefore, Grummer et al. (1990) recommended that fat supplements must be relatively inert in the rumen to reduce the detrimental effects of fat on ruminal carbohydrate fermentation. Canola seed as a fat supplement has been used to increase the energy density of the diet and to alter fatty acid composition of milk fat (Ferlay et al., 1993). The effects of ruminally protected products of CS such as Ca salts (Doreau et al., 1993) and Jet-Sploded® (Khorasani et al., 1992) on ruminal carbohydrate fermentation were evaluated. Doreau et al. (1993) indicated that canola oil (Ca salts at 5.5 or 6.5% added fat) did not decrease ruminal digestion of OM or fiber. Khorasani et al. (1992) reported that increasing levels of ruminally protected CS (Jet-Sploded®) in the diet resulted in substantial changes in ruminal fermentation when fat supplementation exceeded 3% of the diet. Hussein et al. (see fat data in this report) indicated that treatment of whole CS with NaOH and H_2O_2 was successful in protecting fatty acids in CS from ruminal microbial biohydrogenation but allowing digestion of LCFA in CS postruminally. In the present study,

the objective was to determine the effects of fat supplementation from CS at 5% of dietary DM on ruminal fermentation and postruminal digestion of OM, carbohydrates, and energy of diets containing HF or LF that were offered ad libitum to steers.

MATERIALS AND METHODS

Animals, Diets, and Statistical Analyses: Steers, diets and procedures for statistical analyses of data reported here are described previously (see fat data in this report). Data collected at different times after feeding (ruminal pH and concentrations of NH_3 N and VFA) were analyzed as a split-plot design (Gomez and Gomez, 1984) using the GLM procedures of SAS (1985). Main plot variables were steer, period, dietary forage level, CS supplementation, the dietary forage level \times CS supplementation interaction, and the steer \times period \times dietary forage level \times CS supplementation interaction. Sub-plot variables were sampling time and the time \times dietary forage level, time \times CS supplementation, and time \times dietary forage level \times CS supplementation interactions. The steer \times period \times dietary forage level \times CS supplementation interaction was used as the error term to test the significance of main plot variable effects. Tabulated values are least squares means.

Samples and Analyses: Collection, preparation and analyses of all samples (except for ruminal fluid) were described previously (see fat data in this report). On d 18 of each period, samples of ruminal fluid were collected from various locations in the rumen of each steer via a suction pump. Samples were taken just before the morning feeding and at 2 h intervals for 12 h after feeding. Ruminal pH was measured immediately and then samples were prepared for measuring NH_3 N (Chaney and Marbach, 1962) and VFA (Erwin et al., 1961) concentrations. Concentrations of VFA in the ruminal fluid were determined using a Hewlett-Packard Model 5890A Series II gas chromatograph (Hewlett Packard Co., Palo Alto, CA). Samples of dietary ingredients, total mixed diets, Orts, duodenal digesta, and feces were analyzed for NDF (Jeraci et al., 1988), ADF (Goering and Van Soest, 1970), total nonstructural carbohydrates (TNC; Smith, 1969), and GE (Parr Instrument Company, 1988).

RESULTS AND DISCUSSION

No interactions ($P > .05$) between dietary forage level and CS supplementation were observed for DMI, intake and digestion of OM, carbohydrates, or energy, or ruminal characteristics. Therefore, means for the main effects (forage level and CS supplementation) are presented.

Diet Analyses: Chemical composition of diets is presented in Table 1. Diets had similar concentrations of OM and CP but varied in their concentrations of NDF and ADF, reflecting the differences in NDF (51.0 vs 11.0%) and ADF (31.4 vs 3.5%) concentrations measured in corn silage and ground corn, respectively. Concentrations of TNC were higher for diets containing LF than for diets containing HF, reflecting the difference in TNC concentrations between corn and corn silage (71.3 vs 31.6%, respectively). Concentrations of GE were similar for diets containing NCS and were 6.3 to 6.8% higher for diets containing CS.

Intake of Dry Matter: Although diets were fed ad libitum, DMI (kilograms per day) was not affected ($P > .05$) by dietary forage level or CS supplementation (Table 1). However, DMI

as a percentage of BW was higher ($P < .05$) when steers were fed diets containing LF than when they were fed diets containing HF (2.4 vs 2.1%, respectively) and may be attributed to the higher ruminal fermentability and shorter retention time often associated with diets containing LF when compared with diets containing HF. This difference in DMI between the HF and the LF diets corresponds to a 13% increase in DMI over that level (2.1% of BW) predicted by the NRC (1984) for these steers. It is concluded that supplemental fat at 5% of dietary DM from either WTCS or CUCS had no negative effects on DMI by steers when diets were fed ad libitum.

Digestion of Organic Matter and Gross Energy: Daily intakes and apparent digestion of OM and GE are presented in Table 2. Daily intakes of OM or GE were not affected ($P > .05$) by dietary forage level or CS supplementation. Apparent ruminal digestion of OM was not influenced ($P > .05$) by dietary forage level or CS supplementation. Apparent digestion of OM postruminally was not affected ($P > .05$) by CS supplementation but was increased ($P < .05$) by replacing HF with LF in the diet. Apparent digestion of OM in the total tract was decreased ($P < .05$) when steers were fed diets containing HF or diets containing CS.

Digestion of Carbohydrates: Results in Table 3 indicate that daily intakes and digestion of NDF, ADF, and TNC were not affected by CS supplementation. These measurements were influenced ($P < .05$) by dietary forage level. Steers fed diets containing LF had lower ($P < .05$) intakes of NDF and ADF but higher ($P < .05$) intakes of TNC. Apparent digestion of NDF in the rumen, postruminally, and in the total tract were not affected ($P > .05$) by dietary forage level or CS supplementation. Apparent digestion of ADF in the rumen and postruminally also were not affected ($P > .05$) by dietary forage level or CS supplementation. Apparent digestion of ADF in the total tract was not affected ($P > .05$) by CS supplementation but it was higher ($P < .05$) for steers fed diets containing HF than for those fed diets containing LF. Apparent digestion of TNC was not affected ($P > .05$) by CS supplementation but it was lower ($P < .05$) in the rumen and it was higher ($P < .05$) postruminally when steers were fed diets containing LF when compared with diets containing HF.

Ruminal Characteristics: No interactions ($P > .05$) between diet and sampling time were observed for ruminal fermentation characteristics. Therefore, ruminal pH and concentrations of NH_3 N and VFA as affected by dietary forage level and CS supplementation are presented in Table 4. Ruminal pH and concentrations of NH_3 N and total VFA were not affected ($P > .05$) by CS supplementation. Ruminal pH and concentrations of NH_3 N were higher ($P < .05$) when steers were fed diets containing HF than when they were fed diets containing LF. The higher ($P < .05$) ruminal pH associated with feeding HF diets was partially a result of a trend for lower ($P = .09$) concentrations of total VFA when this diet was fed. Feeding diets containing HF increased ($P < .05$) molar proportion of acetate and decreased ($P < .05$) molar proportions of propionate and valerate. Molar proportions of butyrate, isobutyrate and isovalerate were not affected ($P > .05$) by dietary forage level. With the exception of isovalerate, CS supplementation did not affect ($P > .05$) molar proportions of VFA. Molar proportion of isovalerate was increased ($P < .05$) by CS supplementation in either form.

CONCLUSIONS

Supplementation of diets containing HF or LF diets (offered *ad libitum* to steers) with 5% fat from whole CS as partially protected in the rumen (WTCS) or unprotected (CUCS) had no negative effects on feed intake or ruminal fermentation of OM, carbohydrates, and energy. Results suggest that CS in either form may be added to increase the energy density of ruminant diets without compromising ruminal fermentation or total tract digestibility. Another advantage is that feeding CS in either form will minimize or eliminate problems with handling and mixing fat in the preparation of on-farm diets.

REFERENCES

- Chaney, A. L., and E. P. Marbach. 1962. Modified reagents for determination of urea and ammonia. *Clin. Chem.* 8:130.
- Doreau, M., A. Ferlay, and Y. Elmeddah. 1993. Organic matter and nitrogen digestion by dairy cows fed calcium salts of rapeseed oil fatty acids or rapeseed oil. *J. Anim. Sci.* 71:499.
- Erwin, E. S., G. J. Marco, and E. M. Emery. 1961. Volatile fatty acid analysis of blood and rumen fluid by gas chromatography. *J. Dairy Sci.* 44:1768.
- Ferlay, A., J. Chabrot, Y. Elmeddah, and M. Doreau. 1993. Ruminal lipid balance and intestinal digestion by dairy cows fed calcium salts of rapeseed oil fatty acids or rapeseed oil. *J. Anim. Sci.* 71:2237.
- Goering, H. K., and P. J. Van Soest. 1970. Forage fiber analyses (apparatus, reagents, procedures, and some applications). *Agric. Handbook No. 379*. ARS, USDA, Washington, DC.
- Gomez, K. A., and A. A. Gomez. 1984. *Statistical Procedures for Agricultural Research*. p. 187. John Wiley & Sons, Inc. New York.
- Grummer, R. R., M. L. Hatfield, and M. R. Dentine. 1990. Acceptability of fat supplements in four dairy herds. *J. Dairy Sci.* 73:852.
- Jeraci, J. L., T. Hernandez, J. B. Robinson, and P. J. Van Soest. 1988. New and improved procedure for neutral-detergent fiber. *J. Anim. Sci.* 66(Suppl. 1):351 (Abstr.).
- Khorasani, G. R., G. de Boer, P. H. Robinson, and J. J. Kennelly. 1992. Effect of canola fat on ruminal and total tract digestion, plasma hormones, and metabolites in lactating dairy cows. *J. Dairy Sci.* 75:492.

- NRC. 1984. Nutrient Requirements of Beef Cattle (6th Ed.). National Academy Press, Washington, DC.
- Palmquist, D. L., and T. C. Jenkins. 1980. Fat in lactation rations: A review. J. Dairy Sci. 63:1.
- Parr Instrument Company. 1988. Instruction manual for the Parr 1261 isoperibol calorimeter. Parr Instrument Co., Moline, IL.
- SAS. 1985. SAS User's Guide: Statistics (version 5 Ed.). SAS Inst. Inc., Cary, NC.
- Smith, D. 1969. Removing and analyzing total nonstructural carbohydrates from plant tissue. Wisconsin Agric. Exp. Sta. Res. Rep. 41:1.
- Sutton, J. D., R. Knight, A. B. McAllan, and R. H. Smith. 1983. Digestion and synthesis in the rumen of sheep given diets supplemented with free and protected oils. Br. J. Nutr. 49:419.
- Zinn, R. A. 1989. Influence of levels and sources of dietary fat on its comparative feeding value in finishing diets for feedlot steers: Metabolism. J. Anim. Sci. 67:1038.

TABLE 1: CHEMICAL COMPOSITION AND DAILY DRY MATTER INTAKES OF DIETS¹ FED TO STEERS

Item	HF			LF		
	NCS	WTCS	CUCS	NCS	WTCS	CUCS
Chemical composition	----- % of DM -----					
OM	92.3	92.3	92.7	94.0	93.5	94.1
CP	13.2	13.0	13.2	13.4	13.3	13.3
NDF	40.8	42.2	40.9	29.4	32.5	29.8
ADF	23.0	24.1	24.0	12.1	13.5	13.3
TNC ²	38.5	35.1	34.9	53.1	49.8	49.6
Fat ³	3.2	8.6	8.8	4.7	9.8	10.0
GE, Mcal/kg DM	4.10	4.34	4.36	4.14	4.39	4.42
DM intake ⁴						
kg/d	10.0	9.1	8.2	9.7	10.6	9.8
% of BW	2.3	2.1	2.0	2.3	2.6	2.3

¹High (HF) or low (LF) forage diets containing no canola seed (NCS) or canola seed as whole treated (WTCS), or crushed untreated (CUCS).

²Total nonstructural carbohydrates.

³Measured as total long-chain fatty acids (C14:0, C14:1, C16:0, C16:1, C18:0, C18:1, C18:2, C18:3, C20:0, C22:0, C22:1, and C24:0).

⁴No interactions were detected ($P > .05$) and only DM intake as a percentage of BW was higher ($P < .05$) when steers were fed diets containing LF than when they were fed diets containing HF.

TABLE 2: LEAST SQUARES MEANS FOR INTAKE AND APPARENT DIGESTION OF ORGANIC MATTER AND GROSS ENERGY IN STEERS FED DIETS¹ CONTAINING DIFFERENT FORAGE LEVELS AND DIFFERENT CANOLA SEED SUPPLEMENTATIONS

	Dietary forage level			Canola seed supplementation			
Item	HF	LF	SE	NCS	WTCS	CUCS	SE
Intake							
OM, kg/d	8.43	9.44	.37	9.18	9.18	8.43	.43
GE, Mcal/d	38.8	43.4	1.7	40.6	43.1	39.6	2.1
Digestion	----- % of intake -----						
OM							
Ruminally	33.4	30.0	1.9	34.6	28.3	32.2	2.4
Postruminally ²	36.6	42.9	2.1	39.2	41.8	38.3	2.6
Total tract ^{2,3}	70.0	72.9	.8	73.8 ^a	70.1 ^b	70.5 ^b	1.0
GE							
Ruminally ³	25.1	22.8	1.8	27.9 ^a	19.7 ^b	24.2 ^a	2.2
Postruminally	41.3	45.3	1.9	42.3	45.8	41.9	2.4
Total tract ³	66.4	68.1	1.0	70.2 ^a	65.5 ^b	66.0 ^b	1.3

¹High (HF) or low (LF) forage diets containing no canola seed (NCS) or canola seed as whole treated (WTCS), or crushed untreated (CUCS).

²Dietary forage level effect ($P < .05$).

³Canola seed supplementation effect ($P < .05$).

^{a,b}Means in the same row with different superscript letters differ ($P < .05$).

TABLE 3: LEAST SQUARES MEANS FOR INTAKE AND APPARENT DIGESTION OF CARBOHYDRATES IN STEERS FED DIETS¹ CONTAINING DIFFERENT FORAGE LEVELS AND DIFFERENT CANOLA SEED SUPPLEMENTATIONS

	Dietary forage level			Canola seed supplementation			
Item	HF	LF	SE	NCS	WTCS	CUCS	SE
Intake	----- kg/d -----						
NDF ²	3.69	3.09	.15	3.49	3.56	3.11	.20
ADF ²	2.08	1.39	.06	1.83	1.77	1.62	.08
TNC ^{2,3}	3.73	5.65	.15	5.01	4.67	4.38	.19
Digestion	----- % of intake -----						
NDF							
Ruminally	29.6	31.6	2.5	32.1	27.5	32.3	3.3
Postruminally	23.3	20.7	2.3	22.5	24.8	18.7	3.0
Total tract	52.9	52.4	1.8	54.6	52.3	51.0	2.4
ADF							
Ruminally	31.2	27.3	1.9	31.4	25.4	31.0	2.5
Postruminally	15.8	15.9	1.9	14.2	19.6	13.8	2.4
Total tract ²	47.1	43.1	1.2	45.6	45.0	44.7	1.6
TNC ³							
Ruminally ²	61.5	50.9	3.4	57.2	53.7	57.7	4.2
Postruminally ²	34.9	45.8	3.4	39.7	42.3	39.0	4.3
Total tract	96.4	96.7	.4	96.9	96.0	96.7	.6

¹High (HF) or low (LF) forage diets containing no canola seed (NCS) or canola seed as whole treated (WTCS), or crushed untreated (CUCS).

²Dietary forage level effect ($P < .05$).

³Total nonstructural carbohydrates.

TABLE 4: LEAST SQUARES MEANS FOR RUMINAL CHARACTERISTICS OF STEERS FED DIETS¹ CONTAINING DIFFERENT FORAGE LEVELS AND DIFFERENT CANOLA SEED SUPPLEMENTATIONS

Item	Dietary forage level		SE	Canola seed supplementation			SE
	HF	LF		NCS	WTCS	CUCS	
pH ²	6.38	6.10	.08	6.17	6.37	6.18	.10
NH ₃ N, mg/dL ²	11.5	8.3	.65	10.1	9.0	10.7	.79
Total VFA, mM	94.0	101.0	2.6	102.7	91.2	98.5	3.2
Individual VFA	----- mol/100 mol -----						
Acetate ²	65.2	59.2	1.31	60.7	63.7	62.2	1.61
Propionate ²	18.4	24.3	1.61	22.5	19.4	22.2	1.97
Butyrate	13.1	12.7	.74	13.5	13.3	11.8	.91
Isobutyrate	.90	.88	.06	.82	.87	.98	.07
Valerate ²	1.02	1.29	.11	1.26	1.01	1.20	.13
Isovalerate ³	1.41	1.62	.12	1.19 ^b	1.68 ^a	1.66 ^a	.15

¹High (HF) or low (LF) forage diets containing no canola seed (NCS) or canola seed as whole treated (WTCS), or crushed untreated (CUCS).

²Dietary forage level effect ($P < .05$).

³Canola seed supplementation effect ($P < .05$).

^{a,b}Means in the same row with different superscript letters differ ($P < .05$).

ALKALINE HYDROGEN PEROXIDE-TREATED CANOLA SEED FOR RUMINANTS

3. DIGESTION OF PROTEIN

H. S. Hussein, N. R. Merchen, and G. C. Fahey, Jr.

SUMMARY

The objective was to determine the effects of dietary forage level and fat supplementation on ruminal N metabolism, duodenal flows of amino acids (AA), and digestion of N. Six ruminally- and duodenally-cannulated steers were offered six isonitrogenous (13.2% CP; DM basis) diets ad libitum twice daily in a 6×6 Latin square design. Treatments were arranged as a 2×3 factorial with two forage levels and three forms of fat supplementation. The forage levels were high (HF) or low forage (LF) provided by corn silage (70 vs 30% of dietary DM) and the three forms of fat supplementation (from canola seed [CS]) included no CS or CS added at 10% of dietary DM as whole treated (WTCS) with alkaline hydrogen peroxide or crushed untreated CUCS). No interactions between dietary forage level and CS supplementation were observed for any of the measurements evaluated. Duodenal flows of nonammonia N (NAN) and AA were greater for diets containing LF than HF. Efficiency of bacterial protein synthesis and duodenal flows of bacterial N were increased when WTCS was supplemented. Total tract digestibility of N was not altered by dietary forage level or CS supplementation. Results indicate that fat supplementation from CS (at 5% of dietary DM) in either form had no negative effects on ruminal N metabolism or flows of AA to the duodenum and suggest that WTCS may stimulate ruminal bacterial protein synthesis.

INTRODUCTION

Feeding whole oilseeds to ruminants may provide a high quality protein and increase the energy density of the diet while minimizing or eliminating problems associated with handling and mixing fat when preparing on-farm diets. Canola seed seems to be rapidly improving its global position in oilseed production (CS ranks third after soybeans and cottonseed; USDA, 1993). Zinn (1993) emphasized the fact that little research has been conducted to evaluate the protein fraction in CS as a source of N for ruminants. He compared canola meal to soybean meal and reported lower CP concentration (40 vs 53%) and lower ruminal CP degradation (70 vs 80%) for canola meal. However, canola meal was comparable to cottonseed and soybean meals when fed to beef (Thomke, 1980) or dairy (Sanchez and Claypool, 1983) cattle. Little attention has been given to the impact of CS supplementation on ruminal N metabolism. Therefore, the objective was to examine the effects of three forms of CS supplementation of diets containing different forage levels on ruminal N metabolism, duodenal flows of AA, and postruminal digestion of N.

MATERIALS AND METHODS

Steers, diets and procedures for statistical analyses of data reported here are described previously (see fat data in this report). Collection, preparation and analyses of all samples (except for bacteria) were described previously (see fat data in this report). Wet samples of duodenal digesta were analyzed for NH_3 N by steam distillation (Model 323 distillation unit, Büchi

Laboratory-Techniques, Flawil, Switzerland). Samples of diets and duodenal digesta were prepared for AA analysis by acid hydrolysis (150 mg of sample in 15 ml of 6 N HCl at 110°C for 22 h). Concentrations of AA were measured using an AA analyzer (Model 6300, Beckman Instruments, Inc., Palo Alto, CA). Mixed ruminal bacteria were isolated by differential centrifugation from whole ruminal contents that were collected from each steer by a core sampler device (Firkins et al., 1986) at 0400, 0800, 1200, and 1600 on d 18 of each period. Bacterial samples were lyophilized, ground (using a mortar and pestle), and analyzed for DM and Kjeldahl-N (AOAC, 1984). Purine concentrations in bacterial samples and duodenal digesta were determined by the method of Zinn and Owens (1986).

RESULTS AND DISCUSSION

No interactions ($P > .05$) between dietary forage level and CS supplementation were observed for intake, duodenal flows, and digestion of N, or flows of AA to the duodenum. Therefore, results of the main effects are presented in Tables 1 and 2.

Daily intake, flows, and digestion of N are presented in Table 1. Intake of N was not affected ($P > .05$) by dietary forage level or CS supplementation. Flows of total N and NAN to the duodenum were not affected ($P > .05$) by CS supplementation but they were 15% greater ($P < .05$) when steers were fed diets containing LF than when they were fed diets containing HF. Flows of NH_3 N to the duodenum did not differ ($P > .05$) among diets. Flows of dietary N to the duodenum were not affected ($P > .05$) by dietary forage level or CS supplementation. Flows of bacterial N to the duodenum also were not affected ($P > .05$) by dietary forage level but they were increased ($P < .05$) when diets were supplemented with WTCS. The amounts of N excreted in feces were not affected ($P > .05$) by dietary forage level or CS supplementation.

Apparent degradation of dietary CP in the stomach was not affected ($P > .05$) by dietary forage level or CS supplementation and averaged 79.3%. Hussein et al. (see carbohydrate data in this report) indicated that ruminal concentrations of NH_3 N in this study were not affected ($P > .05$) by CS supplementation and averaged 9.9 mg/dL of ruminal fluid. Efficiency of bacterial protein synthesis (grams of N per kilogram OM truly digested in the stomach) tended to increase ($P = .14$) when replacing HF with LF in the diet and increased ($P < .05$) when diets were supplemented with WTCS. Because the amounts of OM truly digested in the stomach were not different ($P > .05$) among diets containing NCS, WTCS, or CUCS (data not shown), the improved efficiency when diets were supplemented with WTCS was a result of greater amounts of bacterial N entering the duodenum (Table 1). Except for increased ($P < .05$) efficiency of bacterial protein synthesis and bacterial N flows to the duodenum when diets were supplemented with WTCS, fat supplementation from WTCS or CUCS did not alter ($P > .05$) ruminal N metabolism, duodenal N flows, or postruminal digestion of N. Digestibility of N in the total tract was not affected ($P > .05$) by dietary forage level or CS supplementation and averaged 61.2%.

Duodenal flows (grams per day) of total, essential, and nonessential AA (Table 2) were greater ($P < .05$) for diets containing LF than diets containing HF. Duodenal flows of total, essential, nonessential, and individual AA (except for Arg and His; data not shown) were not affected (P

> .05) by CS supplementation. Duodenal flows of Arg and His were greater ($P < .05$) when diets were supplemented with WTCS. The greatest amounts of AA of bacterial origin (data not shown) entered the duodenum when diets were supplemented with WTCS.

CONCLUSIONS

Supplementation of diets containing HF or LF with 5% fat from CS in partially ruminally protected (WTCS) or unprotected (CUCS) forms did not affect ruminal N metabolism or duodenal flows of AA negatively. When supplemental fat was from WTCS, the greatest amount of bacterial protein was synthesized in the rumen and, therefore, the greatest amounts of AA of bacterial origin entered the small intestine. Results suggest that WTCS may increase bacterial AA flows to the duodenum.

REFERENCES

- AOAC. 1984. Official Methods of Analysis (14th Ed.). Association of Official Analytical Chemists, Washington, DC.
- Firkins, J. L., L. L. Berger, N. R. Merchen, and G. C. Fahey, Jr. 1986. Effects of forage particle size, level of feed intake and supplemental protein degradability on microbial protein synthesis and site of nutrient digestion in steers. *J. Anim. Sci.* 62:1081.
- Sanchez, J. M., and D. W. Claypool. 1983. Canola meal as a protein supplement in dairy rations. *J. Dairy Sci.* 66:80.
- Thomke, S. 1980. Review of rapeseed meal in animal nutrition. I. Ruminant animals. *J. Am. Oil Chem.* 51:A149.
- USDA. 1993. Oil crops: Situation and outlook. United States Department of Agriculture. Economic Research Service OCS-37. Washington, DC.
- Zinn, R. A. 1993. Characteristics of ruminal and total tract digestion of canola meal and soybean meal in a high-energy diet for feedlot cattle. *J. Anim. Sci.* 71:796.
- Zinn, R. A., and F. N. Owens. 1986. A rapid procedure for purine measurement and its use for estimating net ruminal protein synthesis. *Can. J. Anim. Sci.* 66:157.

TABLE 1: LEAST SQUARES MEANS FOR INTAKE, FLOWS, AND DIGESTION OF NITROGEN IN THE DIGESTIVE TRACT OF STEERS FED DIETS¹ CONTAINING DIFFERENT FORAGE LEVELS AND DIFFERENT CANOLA SEED SUPPLEMENTATIONS

Item	Dietary forage level			Canola seed supplementation			
	HF	LF	SE	NCS	WTCS	CUCS	SE
N intake, g/d	194.5	213.6	8.7	210.0	209.5	192.6	10.8
Duodenal N flow, g/d							
Total ²	184.5	212.3	8.4	194.1	214.0	187.0	10.5
NH ₃	11.4	12.6	1.0	13.0	11.6	11.4	1.2
NAN ²	173.0	199.7	8.0	181.0	202.4	175.7	10.1
Bacterial ³	136.0	153.4	9.7	138.0 ^b	170.8 ^a	125.3 ^b	12.2
Dietary	37.1	46.3	7.8	43.1	31.6	50.4	9.8
Fecal N excretion, g/d	77.8	78.7	2.5	76.6	83.6	74.5	3.1
Degradation of CP in the stomach, % of intake	80.2	78.4	4.2	78.4	84.4	75.2	5.3
Bacterial protein synthesis, g N/kg OMTD ^{3,4}	32.1	36.5	2.0	31.0 ^b	39.5 ^a	32.4 ^b	2.5
N apparently digested postruminally,							
% of intake ²	55.1	62.5	2.2	56.0	61.8	58.5	2.8
% entering ²	57.6	62.2	1.5	59.7	60.3	59.7	1.9
Apparent digestion of N in the total tract, % of intake	59.9	62.5	1.4	62.8	59.8	61.1	1.7

¹High (HF) or low (LF) forage diets containing no canola seed (NCS) or canola seed as whole treated (WTCS), or crushed untreated (CUCS).

²Dietary forage level effect (*P* < .05).

³Canola seed supplementation effect (*P* < .05).

⁴OM truly digested in the stomach.

^{a,b}Means in the same row with different superscript letters differ (*P* < .05).

TABLE 2: LEAST SQUARES MEANS FOR FLOWS OF AMINO ACIDS TO THE DUODENUM OF STEERS FED DIETS¹ CONTAINING DIFFERENT FORAGE LEVELS AND DIFFERENT CANOLA SEED SUPPLEMENTATIONS

Amino acid	Dietary forage level		SE	Canola seed supplementation			SE
	HF	LF		NCS	WTCS	CUCS	
	----- (g/d) -----						
Total ²	885.6	1077.5	45.5	947.8	1082.0	915.0	53.5
Essential ^{2,3}	397.4	483.9	20.2	425.5	484.1	412.3	23.7
Nonessential ^{2,4}	488.2	593.6	25.3	522.3	597.9	502.7	29.9

¹High (HF) or low (LF) forage diets containing no canola seed (NCS) or canola seed as whole treated (WTCS), or crushed untreated (CUCS).

²Dietary forage level effect ($P < .05$).

³Arg, His, Ile, Leu, Lys, Met, Phe, Thr, and Val.

⁴Ala, Asp, Glu, Gly, Pro, Ser, and Tyr.

EFFECTS OF EXTENT OF DEGRADATION OF SUPPLEMENTAL PROTEIN ON RUMINAL FIBER DIGESTION

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SUMMARY

The objective was to determine the effects of altering ruminal CP degradation of soybean meal (SBM) by roasting (Exp. 1) on ruminal characteristics and extents of in situ disappearance of fiber components (Exp. 2). A control diet (8.2% CP) containing oat hulls, corn silage, starch grits, ammoniated corn cobs, and molasses was supplemented to 17.1% CP with unroasted SBM (SBM-0) or SBM roasted at 165°C for 75, 150, or 210 min (SBM-75, SBM-150, and SBM-210, respectively). In Exp. 1, extents of in situ ruminal CP degradation and rates of N disappearance decreased ($P < .05$) linearly with increasing roasting time of SBM. In Exp. 2, five ruminally cannulated steers were used in a 5×5 Latin square design and were fed the five diets during five 11-d periods. On d 11, five substrates (alfalfa hay, orchardgrass hay, corn silage, soy hulls, and wheat straw) were incubated in the rumen for 24 h. Extents of in situ disappearance of fiber components (NDF, ADF, cellulose, hemicellulose, and total dietary fiber [TDF]) were highest ($P < .05$) when the control diet was fed and were lowest ($P < .05$) when the SBM-0 diet was fed. Decreasing the availability of SBM protein in the diet by roasting increased ($P \leq .10$) extents of in situ disappearance of fiber components linearly. These extents were similar for steers fed the control diet or the diet containing SBM-210. Ruminal concentrations of NH_3 N, branched-chain VFA, and valerate were highest ($P < .05$) and ruminal pH was lowest ($P < .05$) when the SBM-0 diet was fed. Results indicated a rapid ruminal fermentation of both protein and readily available carbohydrates of SBM (resulting in pH below 6.0) during the first 4.5 h after feeding the SBM-0 diet. Making both protein and readily available carbohydrates of SBM less fermentable by roasting slowed early fermentation processes, maintained higher ruminal pH, and encouraged earlier and faster ruminal fiber digestion.

INTRODUCTION

Ruminal fiber digestion may be limited by dietary factors that alter nutrient availability to ruminal cellulolytic bacteria. The major cellulolytic bacterial species can utilize NH_3 as the main source of N and require branched-chain VFA as essential growth factors for the biosynthesis of branched-chain amino acids and higher branched-chain fatty acids (Bryant, 1973). Decreasing ruminal CP degradation of the diet by replacing SBM with fish meal increased ruminal fiber digestion (McCarthy et al., 1989; Hussein et al., 1991a). Hussein et al. (1991b) found that fish meal protein was digested in the rumen at a slower rate than that of SBM. Feeding proteins resistant to ruminal degradation resulted in a more gradual release of NH_3 N, peptides, and branched-chain VFA (Veen, 1986). Therefore, these essential growth factors were made available to the ruminal cellulolytic bacteria for a longer period of time after feeding. To examine the relationship between ruminal protein degradation and fiber digestion without inducing variations associated with different protein sources, a control diet (N was mostly from NH_3) was compared to diets containing SBM that was roasted for different lengths of time. The objectives of this study were to determine the effects of altering ruminal CP degradation of SBM on ruminal characteristics and extent of in situ ruminal fiber disappearance of selected forages

and fibrous byproducts.

MATERIALS AND METHODS

Animals and Diets. Five ruminally cannulated Angus \times Simmental steers (mean BW \pm SD = 471 \pm 16 kg) were used in two in situ experiments (2 steers were used in Exp. 1 and five steers were used in Exp. 2). Five diets (Table 1) including a control and four SBM-containing diets were fed. In the SBM-containing diets, SBM was either unroasted (SBM-0) or roasted (SBM-75, SBM-150, and SBM-210) at 165°C for 75, 150, or 210 min, respectively. The control (basal) diet was formulated to contain 8.2% CP (N was mostly NH₃ from urea and ammoniated corn cobs) on a DM basis. Soybean meal provided approximately 50% of total dietary CP in the SBM-containing diets.

Experiment 1. To determine extent of ruminal CP degradation in response to roasting time, the four types of SBM were evaluated in situ. Samples of SBM were ground (1 mm) and .5 g DM was weighed into Dacron bags (6 cm \times 10 cm). Two ruminally cannulated steers were used and were offered the SBM-0 diet ad libitum for 10 d. On d 11, all bags (except for the 0-h) were incubated in the rumen of each steer at the time of the morning feeding. Bags were removed from the rumen 2, 4, 8, 12, 16, and 24 h post-immersion, rinsed, dried (at 57°C for 48 h), and weighed. Nitrogen remaining in bags was determined by the Kjeldahl procedure (AOAC, 1984). Extent of CP degradation was estimated by the equation of Mathers and Miller (1981). A rate constant for passage (k_p) of undegraded CP from the rumen of .05 h⁻¹ was used. The rate (k_d) at which N disappeared from the rumen (rate of disappearance) was estimated as the slope of the regression of the natural logarithm of the percentage of the nonsoluble N remaining vs incubation time in the rumen (i.e., 2 to 24 h).

Experiment 2. Five ruminally cannulated steers were used in a 5 \times 5 Latin square design. Steers were offered the five experimental diets (Tables 1 and 2) at a restricted feed intake (90% of ad libitum feed intake) during the five periods (included 9 d adaptation followed by ruminal measurements on d 10 and incubation of fibrous substrates on d 11). On d 10 of each period, ruminal fluid was collected (just before feeding and at 90 min intervals for 12 h after feeding) and pH was measured immediately. Ruminal fluid samples were prepared for subsequent analyses of NH₃ N (Chaney and Marbach, 1962) and VFA (Erwin et al., 1962) concentrations. On d 11 of each period, substrates were subjected to in situ ruminal fermentation. Five substrates (Table 3) including three forages (alfalfa hay, orchardgrass hay, and corn silage) and two fibrous byproducts (soy hulls and wheat straw) were evaluated in this experiment. Substrates were ground (1 mm) and 4 g DM was weighed into Dacron bags (7 cm \times 13 cm). Dacron bags (6 bags substrate⁻¹ steer⁻¹) were incubated in the rumen at the time of the morning feeding. After 24 h of ruminal incubation, bags were removed, rinsed, dried (at 57°C for 48 h), and weighed. Residues for the same substrate (6 bags) incubated in the same steer were composited for analyses. A total of 125 composite residue samples (5 substrates \times 5 steers \times 5 periods) were used to determine extents of in situ ruminal disappearance of substrates. Samples were analyzed for DM, OM, and Kjeldahl N (AOAC, 1984) and also for NDF (Jeraci et al., 1988), ADF and ADL (Goering and Van Soest, 1970), and TDF (Prosky et al., 1985).

Statistical Analysis. Results of both experiments were analyzed using the GLM procedures of

SAS (1985). Data collected in Exp. 1 were analyzed as a completely randomized design. Data collected in Exp. 2 were analyzed as a split-plot design. Treatment means in Exp. 1 were compared using orthogonal contrasts (Steel and Torrie, 1980) to test for linear, quadratic, and cubic responses to roasting time of SBM. In Exp. 2, the substrate \times diet interaction was not significant ($P > .05$). Means for effects of diet on feed intake, ruminal characteristics, and extents of in situ disappearance of fibrous substrates were compared by the following contrasts: 1) control diet vs diets containing SBM, and 2) linear, quadratic, and cubic responses to roasting time of SBM.

RESULTS AND DISCUSSION

Experiment 1. Results of the in situ evaluation of roasted SBM are presented in Table 4. Extent of DM degradation and rate of DM disappearance from Dacron bags decreased ($P < .05$) linearly with increasing roasting time of SBM. Extent of CP degradation and rate of N disappearance also decreased ($P < .05$) linearly with increasing roasting time of SBM.

Experiment 2. Daily intakes of DM by steers, ruminal characteristics, and extents of in situ disappearance of fiber components of the substrates are presented in Table 5. Daily intakes of DM were higher ($P < .05$) for diets containing SBM vs the control diet. Ruminal concentration of NH_3 N was lower ($P < .05$) when steers were fed the control diet than when fed the SBM diets. Adding the SBM-0 to the control diet resulted in the highest ruminal concentration of NH_3 N (9.17 mg/dL). Increasing roasting time of SBM decreased ($P < .05$) ruminal concentration of NH_3 N linearly. This decrease in ruminal NH_3 N concentration in response to increasing roasting time of SBM is consistent with in situ data in Table 4. Ruminal concentrations of isobutyrate, isovalerate, and valerate were highest ($P < .05$) when the SBM-0 diet was fed and then decreased ($P < .05$) linearly with increasing roasting time of SBM, indicating a decrease in extent of ruminal degradation of CP (Table 4) and deamination of amino acids.

The comparison of the control diet versus diets containing SBM indicated similar extents of in situ disappearance of NDF (27.7 vs 25.3%; $P = .23$), ADF (21.5 vs 19.3%; $P = .27$), cellulose (21.1 vs 18.7%; $P = .33$), hemicellulose (42.3 vs 39.7%; $P = .25$), and TDF (32.0 vs 30.0%; $P = .20$), respectively. A decrease in extents of in situ disappearance of these fiber components occurred when the SBM-0 supplemented the control diet. Linear increases ($P \leq .10$) in extents of in situ disappearance of NDF, hemicellulose, and TDF with increasing roasting time of SBM were detected. Extents of in situ disappearance of ADF and cellulose showed trends for linear ($P = .12$ and $P = .29$, respectively) responses to roasting time of SBM.

Mean values for extents of in situ disappearance of fiber components were highest when the control diet (having no SBM and containing N that was mostly NH_3 from urea and ammoniated corn cobs) was fed and were lowest when the SBM-0 (containing CP that was mostly available for ruminal microbial degradation; Table 4) supplemented the control diet. Because steers fed the SBM-0 diet maintained the highest concentrations of NH_3 N, branched-chain VFA, and valerate (Table 5), it seems that factors other than these essential growth factors were likely to be responsible for the depression in ruminal fiber digestion when the SBM-0 diet was fed to the steers (Table 5). Despite the fact that the diet \times time after feeding interactions were not significant ($P > .05$) for ruminal pH or total VFA concentrations (data not shown), the SBM-0

diet tended to maintain higher ($P = .12$) ruminal concentrations of total VFA (146.3, 150.9, and 145.5 mM) than the control diet (112.9, 123.6, and 126.3 mM) at 1.5, 3, and 4.5 h after feeding, respectively. These concentrations resulted in numerically lower ruminal pH for the SBM-0 diet (6.15, 5.9, 5.85, and 6.08) than for the control diet (6.49, 6.15, 6.09, and 6.25) at 1.5, 3, 4.5, and 6 h after feeding, respectively. These observations indicate that rapid fermentation took place during the first 4.5 h after feeding when the SBM-0 diet was fed. Results in Exp. 1 indicated linear ($P < .05$) extents of disappearance of DM (62, 44, 32, and 32%) and N (53, 26, 14, and 11%) when SBM-0, SBM-75, SBM-150, and SBM-210, respectively, were incubated in the rumen for 4 h (data not shown). The chemical composition of SBM (data not shown) indicated that concentrations of total nonstructural carbohydrates (TNC) and starch were 19.8 and 2.5%, respectively. Because TNC is composed of starch and simple sugars, readily available carbohydrates in SBM-0 were mostly simple sugars that were fermented rapidly (within the first 4.5 h after feeding). Increasing roasting time of SBM increased formation of Maillard products and decreased ruminal fermentability of both protein and these simple sugars participating in the Maillard reaction (Hussein et al., 1995).

CONCLUSIONS

In addition to the known advantages of supplementing ruminant diets with low ruminally degradable protein supplements (i.e., increasing the quantity and/or improving the profile of amino acids reaching the duodenum), they seem to have an important role in ruminal fiber digestion. Feeding low ruminally degradable protein supplements (e.g., roasted SBM) to steers maintained higher ruminal pH without stimulating ruminal fiber digestion above the level detected for the basal diet. Replacing high ruminally degradable protein with low degradable protein supplements eliminates the negative effects on fiber digestion that are associated with feeding high ruminally degradable protein supplements.

REFERENCES

- AOAC. 1984. Official Methods of Analysis (14th Ed.). Association of Official Analytical Chemists, Washington, DC.
- Bryant, M. P. 1973. Nutritional requirements of the predominant rumen cellulolytic bacteria. Fed. Proc. 32:1809.
- Chaney, A. L., and E. P. Marbach. 1962. Modified reagents for determination of urea and ammonia. Clin. Chem. 8:130.
- Erwin, E. G., G. J. Marco, and E. M. Emery. 1961. Volatile fatty acid analyses of blood and rumen fluid by gas chromatography. J. Dairy Sci. 44:1768.
- Goering, H. K., and P. J. Van Soest. 1970. Forage fiber analyses (apparatus, reagents, procedures, and some applications). Agric. Handbook No. 379. ARS, USDA, Washington, DC.

- Hussein, H. S., R. M. Jordan, and M. D. Stern. 1991a. Ruminant protein metabolism and intestinal amino acid utilization as affected by dietary protein and carbohydrate sources in sheep. *J. Anim. Sci.* 69:2134.
- Hussein, H. S., M. D. Stern, and R. M. Jordan. 1991b. Influence of dietary protein and carbohydrate sources on nitrogen metabolism and carbohydrate fermentation by ruminal microbes in continuous culture. *J. Anim. Sci.* 69:2123.
- Hussein, H. S., B. Demjanec, N. R. Merchen, and C. G. Aldrich. 1995. Effect of roasting on site and extent of digestion of soybean meal by sheep: 2. Digestion of artifacts of heating. *J. Anim. Sci.* (In press).
- Jeraci, J. L., T. Hernandez, J. B. Robinson, and P. J. Van Soest. 1988. New and improved procedure for neutral-detergent fiber. *J. Anim. Sci.* 66(Suppl. 1):351 (Abstr.).
- McCarthy, R. D., Jr., T. H. Klusmeyer, J. L. Vicini, J. H. Clark, and D. R. Nelson. 1989. Effects of source of protein and carbohydrate on ruminal fermentation and passage of nutrients to the small intestine of lactating cows. *J. Dairy Sci.* 72:2002.
- Prosky, L., N.-G. Asp, I. Furda, J. W. DeVries, T. F. Schweizer, and B. F. Harland. 1985. Determination of total dietary fiber in food and food products: Collaborative study. *J. Assoc. Off. Anal. Chem.* 68:677.
- SAS. 1985. *SAS User's Guide: Statistics (version 5 Ed.)*. SAS Inst. Inc., Cary, NC.
- Steel, R. G. D., and J. H. Torrie. 1980. *Principles and Procedures of Statistics: A Biometrical Approach (2nd Ed.)*. McGraw-Hill Publishing Co., New York.
- Veen, W. A. G. 1986. The influence of slowly and rapidly degradable concentrate protein on a number of rumen parameters in dairy cattle. *Neth. J. Agric. Sci.* 34:199.

TABLE 1: INGREDIENT COMPOSITION OF DIETS FED TO STEERS

Ingredient	Diets ¹	
	Control	SBM
	----- % of DM -----	
Ammoniated corn cobs	20.0	20.0
Corn silage	25.0	25.0
Oat hulls	28.0	12.0
Starch grits	20.7	20.5
Soybean meal	--	16.2
Dried molasses	5.0	5.0
Supplement ²	1.3	1.3

¹Diets containing soybean meal (SBM) were SBM-0, SBM-75, SBM-150, and SBM-210 where SBM was roasted at 165°C for 0, 75, 150, or 210 min, respectively.

²Total of .85% urea, .20% Na₂SO₄, .15% vitamins and minerals mix, and .1% NaCl.

TABLE 2: CHEMICAL COMPOSITION OF DIETS FED TO STEERS

Item	Diets ¹				
	Control	SBM-0	SBM-75	SBM-150	SBM-210
	----- % of DM -----				
OM	94.5	94.2	94.4	94.3	94.1
CP	8.2	16.5	17.2	17.0	17.5
NDF	48.9	38.4	41.6	43.8	45.9
ADF	29.9	23.4	23.2	24.0	25.9

¹Control or diets containing soybean meal (SBM) roasted at 165°C for 0, 75, 150, or 210 min (i.e., SBM-0, SBM-75, SBM-150, and SBM-210, respectively).

TABLE 3: CHEMICAL COMPOSITION OF SUBSTRATES INCUBATED IN SITU (EXPERIMENT 2)

Item	Substrates				
	Alfalfa hay	Orchardgrass hay	Corn silage	Wheat straw	Soy hulls
	----- % of DM -----				
OM	92.0	90.9	93.5	91.3	95.0
CP	13.6	15.8	9.6	4.8	11.2
NDF	55.5	57.5	56.6	77.9	67.5
ADF	41.4	41.2	36.0	52.0	47.6
ADL	9.6	10.5	9.4	10.3	2.0
Total dietary fiber	60.4	65.6	55.1	76.5	79.1

TABLE 4: IN SITU EVALUATION OF SOYBEAN MEAL ROASTED¹ FOR DIFFERENT TIMES (EXPERIMENT 1)

Item	Roasting time, min				SE
	0	75	150	210	
DM degradation ^{2,3} , %	87.2	74.4	49.9	39.7	.9
Rate of DM disappearance ^{3,4} , h ⁻¹	.164	.068	.020	.010	.002
CP degradation ^{2,3} , %	87.6	65.7	31.2	13.4	2.0
Rate of N disappearance ^{3,4} , h ⁻¹	.212	.063	.016	.003	.007

¹Roasting temperature = 165°C.

²Determined according to the equation of Mathers and Miller (1981) at rate constant for passage (K_p) of undegraded CP from the rumen of .05 h⁻¹.

³Linear response ($P < .05$) to roasting time of soybean meal.

⁴Estimated as the slope of the regression of the natural logarithm of the percentage remaining vs ruminal incubation time (i.e., 2 to 24 h).

TABLE 5: FEED INTAKE, RUMINAL CHARACTERISTICS AND IN SITU DISAPPEARANCE OF FIBER COMPONENTS IN STEERS FED DIETS CONTAINING ROASTED SOYBEAN MEAL (EXPERIMENT 2)

Item	Diets ¹					SE
	Control	SBM-0	SBM-75	SBM-150	SBM-210	
DM intake, kg/d ²	8.10	8.58	8.66	8.64	8.74	.16
Ruminal characteristics ³						
pH	6.48	6.30	6.41	6.38	6.48	.03
NH ₃ N, mg/dL ²	2.75	9.17	7.31	5.42	3.88	.41
VFA, mM						
Total	110.0	123.8	114.3	115.3	109.6	1.5
Isobutyrate	1.08	1.35	1.27	1.13	1.01	.02
Isovalerate	2.12	2.55	2.19	1.90	1.85	.04
Valerate	1.15	1.52	1.28	1.21	1.00	.03
In situ disappearance ^{4,5}	----- % -----					
NDF	27.7	22.2	25.5	26.9	26.6	.6
ADF	21.5	16.2	19.6	21.4	20.0	.6
Cellulose	21.1	15.4	19.2	20.6	19.7	.6
Hemicellulose	42.3	36.6	39.8	39.9	42.3	1.1
Total dietary fiber	32.0	27.9	29.7	31.1	31.1	.6

¹Control or diets containing soybean meal (SBM) roasted at 165°C for 0, 75, 150, or 210 min (i.e., SBM-0, SBM-75, SBM-150, and SBM-210, respectively).

²Control diet vs diets containing SBM ($P < .05$).

³Linear response to roasting time of SBM ($P < .05$).

⁴Disappearance after 24 h of ruminal incubation.

⁵Linear response to roasting time of SBM (NDF and hemicellulose; $P = .07$, and total dietary fiber; $P = .09$).

WET CORN GLUTEN FEED FOR GROWING-FINISHING HEIFERS THAT WERE INITIALLY FED AD LIBITUM OR AT RESTRICTED FEED INTAKE

H. S. Hussein, L. L. Berger, and T. G. Nash

SUMMARY

The energy value of wet corn gluten feed (WCGF) and that of corn were compared in a growing-finishing trial. Diets were initially offered ad libitum (AL) or at restricted feed intake (RFI; 80% of AL) to 144 beef heifers (6 treatments; 3 pens of 8 heifers/treatment). Treatments were levels of WCGF (on DM basis) in corn silage-based diets (AL; 25 or 50% WCGF) or corn-based diets (RFI; 0, 25, 50, or 75% WCGF) during growing (127 d). During finishing (84 d), all diets contained 5% corn silage by replacing corn silage with corn in diets that were offered AL. Heifers that were initially at AL had similar ($P > .1$) feedlot performance (during growing and during the whole trial), digestibility of nutrients (OM, NDF, CP, and GE), and carcass characteristics. During finishing, however, these heifers had better ($P = .06$) ADG and gain/feed when 25% WCGF was fed. Heifers that were initially at RFI, showed a linear decrease ($P < .01$) in ADG and gain/feed during growing with increasing dietary level of WCGF. However, increasing dietary level of WCGF resulted in a quadratic ($P = .02$) response in ADG and gain/feed during finishing and also in a quadratic ($P = .07$) response in ADG and a linear ($P = .005$) decrease in gain/feed during the whole trial allowing the best performance to be achieved at the 25 and 50% levels of WCGF. Increasing the level of WCGF in diets of heifers that were initially at RFI did not affect ($P > .1$) digestibility of nutrients but it improved some carcass characteristics linearly, including backfat thickness ($P = .04$), liver abscess ($P = .02$), and yield grade ($P = .13$). Results suggest that WCGF can be fed at 25 or 50% of dietary DM, replacing corn and soybean meal, without depressing feedlot performance, digestibility of nutrients, or carcass characteristics. In addition, restricting feeding during growing may be a strategy that improves the utilization of WCGF at these levels.

INTRODUCTION

Because of the ability of the ruminal microbes to ferment fibrous feeds and to utilize nonprotein nitrogen, by-product feeds have been and will continue to be important feeds for ruminants. By-product feeds that have been properly processed, stored, and incorporated into well-balanced diets should play an increasingly important role in the feeding of beef cattle. Wet corn gluten feed is one of the major by-products of the corn wet-milling industry (Anonymous, 1982). Currently, most of WCGF produced in the U.S. is dried and exported to the European Common Market. This situation may change in the near future so that the amount of WCGF marketed domestically could increase dramatically because of an increase in WCGF production, a potential decrease in its export, and a high energy cost to dry it before being exported. Positive responses to including WCGF in feedlot diets (Firkins et al., 1985; Trenkle, 1987) have been reported. Energy in WCGF was estimated (NRC, 1984) to be 10% lower than that in corn because of its high content of NDF (43.7% of DM) that is digested in the rumen at a much slower rate than starch in corn. Because this estimate was

based on AL feeding situations, it was hypothesized that feeding WCGF at a RFI may increase its energy value because of a slower rate of passage from the rumen and a potential higher ruminal pH to improve fiber digestion. Sainz and Oltjen (unpublished data) showed that restriction of feed intake during growing improved ADG and gain/feed of steers fed the high-corn diet and attributed the response to decreased maintenance requirements. Therefore, the objective was to compare the energy value of WCGF to that of corn in feedlot when diets were initially offered AL or at RFI.

MATERIALS AND METHODS

Heifers and Diets. One hundred and forty-four Angus-cross heifers were used in a completely randomized block (pen location in the barn) design experiment (6 treatments; 3 pens of 8 heifers/treatment). Treatments were graded levels of WCGF in diets (Table 1) containing high corn silage (diets 1 and 2 offered AL) or diets containing only 5% corn silage (diets 3, 4, 5 and 6; offered at RFI [80% of AL]) during growing (127 d). During finishing (84 d), all diets were offered AL and contained similar amounts of corn silage (by replacing corn silage with corn in diets 1 and 2, making them similar to diet 4 and 5, respectively). Two supplements (Table 2) were used alone or together to provide 15% of DM of all six diets (Table 2). These supplements were added to the diets to balance for minerals and vitamins and to assure that CP in the diets met or exceeded the CP requirements that were recommended (NRC, 1984) for these heifers. Diets were fed fresh once daily and the amounts of feed intake were monitored. Three heifers were removed from the trial for reasons not related to treatment.

Digestibility of Nutrients. Digestibilities of DM, OM, NDF, CP, and GE were estimated during the last 12-d period of each of the growing and finishing phases of the trial using Cr as a digestibility marker. This was achieved by adding Cr_2O_3 to the diets at the time of mixing to allow for 7 g of Cr heifer⁻¹ d⁻¹. Fecal grab samples were collected from each heifer 3 times on d 12 and were composited by pen. Samples of dietary feed ingredients were collected for the last 4 d of each period and composited for each ingredient. Feeds and fecal samples were analyzed for concentrations of DM, OM, and Kjeldahl-N (AOAC, 1984). Samples also were analyzed for concentrations of NDF (Jeraci et al., 1988), ADF (Goering and Van Soest, 1970), and GE (Parr Instrument Company, 1988). Concentrations of Cr in fecal samples were measured using an atomic absorption spectrophotometer after preparation according to the method of Williams et al. (1962).

Carcass Characteristics. Heifers were slaughtered at a commercial packing plant and their carcasses were evaluated by University of Illinois personnel at 24 h postmortem.

Statistical Analyses. Data (feedlot performance, nutrient digestibility, and carcass characteristics) were analyzed as a randomized complete block design (Steel and Torrie, 1980) according to the GLM procedures of SAS (1985). Pen was the experimental unit for data of feedlot performance and nutrient digestibility, but heifer was the experimental unit for the carcass data. Treatment means were compared (orthogonal contrasts; Steel and Torrie, 1980) by the following contrasts: 1) treatment 1 vs treatment 2 (diets containing 25 and 50% WCGF and were offered AL during the growing phase), 2) treatment 3 vs treatments 4,

5, and 6 (diet containing no WCGF vs those containing WCGF and were offered at RFI during the growing phase), and both 3) linear and 4) quadratic responses to WCGF supplementation when diets were offered at RFI during the growing phase.

RESULTS AND DISCUSSION

Feedlot Performance. Feedlot performance data are presented in Table 3. During the growing phase, heifers fed diets containing WCGF gained slower ($P = .008$) than those fed the high-corn (no WCGF) diet when diets were offered at RFI. The decrease in ADG was linear ($P = .003$) with increasing the level of WCGF in the diet. Rate of gain was not affected ($P > .1$) by dietary level of WCGF when diets were offered AL. Offering diets containing 25 or 50% WCGF to heifers AL did not affect ($P > .1$) efficiency of feed utilization. However, including WCGF in the diets that were offered at RFI resulted in a linear decrease in gain/feed.

Heifers that were initially at AL feed intake gained faster ($P = .06$) and were more ($P = .09$) efficient in utilizing feed when they were fed the diet containing 25% WCGF versus that containing 50% WCGF. Heifers that were initially at RFI showed positive responses to the inclusion of WCGF in the diet. Feeding WCGF tended to increase ($P = .14$) ADG by 9.3% and the response to increasing level of WCGF in the diet was quadratic ($P = .02$) with the highest ADG being achieved at the 25% level of WCGF. A quadratic ($P = .02$) response to WCGF also was observed for feed efficiency with the heifers receiving WCGF at the 25 or 50% levels being the most efficient.

The performance during the 211-d growing-finishing trial showed that heifers that were initially at AL feed intake had similar ($P > .1$) ADG, DMI, and gain/feed. However, heifers that were initially at RFI showed a quadratic ($P = .07$) response to increasing level of WCGF in the diet, with a decrease in ADG at the 75% level. Inclusion of WCGF in the diet decreased ($P = .03$) gain/feed by an average of 6% with most of the depression occurring at the 75% level of WCGF.

Digestibility of Nutrients. Intake of DM and digestibility of nutrients during the two periods where Cr was fed are presented in Table 4. No effects ($P > .2$) of dietary treatments were detected on these measurements. The lack of treatment effects on total tract digestibility of nutrients to explain differences detected in performance may be explained by a shift in site of nutrient digestion without affecting extent of digestion.

Carcass Characteristics. Carcass characteristics of heifers as affected by dietary treatments are presented in Table 5. Heifers that were initially at AL feed intake had similar ($P > .1$) carcass measurements irrespective of level (25 or 50%) of WCGF in the diet. However, heifers that were initially at RFI showed some responses to inclusion of WCGF in their diets. Backfat thickness decreased ($P = .01$) from 1.40 cm to 1.15 cm due to feeding WCGF and this response was linear ($P = .04$) with increasing level of WCGF in the diet. These increasing levels of WCGF resulted in a linear decrease in marbling ($P = .04$), USDA choice carcasses ($P = .04$), and liver abscesses ($P = .02$), with the 75% level of WCGF having the most dramatic effect.

CONCLUSIONS

In growing-finishing diets for beef cattle, WCGF can substitute up to 25 or 50% of corn without negative effects on feedlot performance, digestibility of nutrients, or carcass characteristics. In addition, restricting feed intake during growing may be a strategy that improves the utilization of WCGF at these levels. Because feed costs account for about 70% of the total costs in beef production systems, feeding WCGF also may be one means of reducing feed costs for many beef producers in areas where corn is produced and processed.

REFERENCES

- Anonymous. 1982. Corn Wet-Milled Feed Products. (2nd Ed.). Corn Refiners Assoc., Inc., Washington, DC.
- AOAC. 1984. Official Methods of Analysis (14th Ed.). Association of Official Analytical Chemists, Washington, DC.
- Firkins, J. L., L. L. Berger, and G. C. Fahey, Jr. 1985. Evaluation of wet and dry distillers grains and wet and dry corn gluten feeds for ruminants. *J. Anim. Sci.* 60:847.
- Goering, H. K., and P. J. Van Soest. 1970. Forage fiber analyses (apparatus, reagents, procedures, and some applications). Agric. Handbook No. 379. ARS, USDA, Washington, DC.
- Jeraci, J. L., T. Hernandez, J. B. Robinson, and P. J. Van Soest. 1988. New and improved procedure for neutral-detergent fiber. *J. Anim. Sci.* 66(Suppl. 1):351 (Abstr.).
- NRC. 1984. Nutrient Requirements of Beef Cattle (6th Ed.). National Academy Press, Washington, DC.
- Parr Instrument Company. 1988. Instruction Manual for the Parr 1261 isoperibol calorimeter. Parr Instrument Co., Moline, IL.
- SAS. 1985. SAS User's Guide: Statistics (version 5 Ed.). SAS Inst. Inc., Cary, NC.
- Steel, R. G. D., and J. H. Torrie. 1980. Principles and Procedures of Statistics: A Biometrical Approach (2nd Ed.). McGraw-Hill Publishing Co., New York.
- Trenkle, A. H. 1987. Use of wet corn gluten feed in no roughage diets for finishing cattle. A.S. Leaflet R442, p 61. Iowa State Univ., Ames.
- Williams, C. H., D. J. David, and O. Iismaa. 1962. The determination of chromic oxide in faeces samples by atomic absorption spectrophotometry. *J. Agric. Sci. (Camb.)* 59:381.

TABLE 1: INGREDIENT AND CHEMICAL COMPOSITIONS OF DIETS FED TO BEEF HEIFERS

	Diets					
Item	1	2	3	4	5	6
	----- % of DM -----					
Ingredient composition						
High moisture corn	--	--	80	55	30	5
Corn silage ¹	60	35	5	5	5	5
Wet corn gluten feed ²	25	50	--	25	50	75
Supplement A ³	6	--	15	5	--	--
Supplement B ³	9	15	--	10	15	15
Chemical composition						
OM	92.1	91.5	94.6	93.5	92.3	90.8
CP	13.3	14.8	14.5	13.9	15.4	18.7
NDF	37.4	38.9	19.9	26.7	33.0	38.8
ADF	18.5	15.4	4.5	6.7	8.9	11.3
GE, Mcal/kg DM	4.08	4.09	4.09	4.09	4.10	4.12

¹Containing (on a DM basis) 95.8% OM, 40.3% NDF, 24.6% ADF, and 7.1% CP.

²42% DM and containing (on a DM basis) 92.5% OM, 43.7% NDF, 12.5% ADF, and 22.5% CP.

³Supplements A (46.3% CP; DM basis) and B (7.2% CP; DM basis) were formulated (Table 2) and added to the diets to balance for minerals and vitamins and to assure that CP requirements by the heifers (NRC, 1984) were met.

TABLE 2: INGREDIENT COMPOSITION OF SUPPLEMENTS FED TO BEEF HEIFERS

Ingredient	Supplement	
	A	B
	----- % of DM -----	
Soybean meal	68.0	--
Urea	3.02	--
Dicalcium phosphate	2.74	--
Limestone	14.66	18.73
Potassium bicarbonate	1.16	--
Trace mineralized salt ¹	2.69	2.67
Rumensin-80 ²	.14	.14
Tylan-40 ³	.08	.08
Thiamine	.40	.40
Vitamin premix ⁴	.19	.20
Ground corn	6.92	77.78

¹Composition (g/100 g): NaCl (97 to 99), Zn (> .35), Fe (> .2), Mn (> .18), Cu (> .035), I (> .01), Se (> .009), Co (> .006).

²Contains 176 g monensin/kg.

³Contains 88 g tylosin/kg.

⁴Composition (per gram): vitamin A (3,300 IU), vitamin D3 (330 IU), vitamin E (44 IU), vitamin K (2.2 mg), vitamin B12 (.0176 mg), riboflavin (4.4 mg), D-pantothenic acid (12.1 mg), niacin (16.5), choline chloride (165.0 mg).

TABLE 3: FEEDLOT PERFORMANCE OF BEEF HEIFERS AS AFFECTED BY LEVEL OF WET CORN GLUTEN FEED IN DIETS OFFERED AT TWO LEVELS OF FEED INTAKE DURING GROWING OR AD LIBITUM DURING FINISHING

Item	Treatments ¹												Contrasts ² (<i>P</i> =)				
	1		2		3		4		5		6		SE	1	2	3	4
	LIB	RES	LIB	RES	LIB	RES	LIB	RES	LIB	RES	LIB	RES					
No. of heifers	23	23	23	23	24	24	24	24	24	24	24						
Initial wt., kg	202.7	202.8	202.8	206.5	208.7	208.7	205.6	204.0	204.0	204.0	204.0	2.0	.9	.9	.3	.4	.4
Growing phase (127 d):																	
ADG, kg	1.14	1.19	1.19	1.22	1.14	1.14	1.12	1.04	1.04	1.04	1.04	.03	.4	.008	.003	.9	.9
DMI, kg	6.33	6.36	6.36	5.10	5.20	5.20	5.09	5.09	5.09	5.09	5.09	.10	.9	.8	.8	.6	.6
Gain/feed	.180	.186	.186	.239	.220	.220	.220	.205	.205	.205	.205	.007	.6	.02	.008	.9	.9
Finishing phase (84 d):																	
ADG, kg	1.11	.97	.97	.97	1.14	1.14	1.07	.97	.97	.97	.97	.05	.06	.14	.7	.02	.02
DMI, kg	6.59	6.16	6.16	6.20	6.88	6.88	6.52	6.52	6.52	6.52	6.52	.20	.16	.08	.5	.12	.12
Gain/feed	.169	.158	.158	.157	.166	.166	.165	.149	.149	.149	.149	.004	.09	.6	.19	.02	.02
The whole trial (211 d):																	
ADG, kg	1.13	1.10	1.10	1.12	1.14	1.14	1.10	1.01	1.01	1.01	1.01	.03	.5	.3	.2	.07	.07
DMI, kg	6.43	6.28	6.28	5.53	5.87	5.87	5.66	5.66	5.66	5.66	5.66	.11	.4	.17	.8	.17	.17
Gain/feed	.175	.176	.176	.202	.195	.195	.195	.179	.179	.179	.179	.004	.9	.03	.005	.4	.4

¹Treatments were levels of wet corn gluten feed (WCGF; as a percentage of DM) in diets that were offered ad libitum (LIB) or at restricted (RES) feed intake during the growing phase.

²Contrasts were 1) treatment 1 vs treatment 2 (diets containing WCGF; offered ad libitum during the growing phase), 2) treatment 3 vs treatments 4, 5, and 6 (diet containing no WCGF vs those containing WCGF; offered at restricted feed intake during the growing phase), and both 3) linear and quadratic responses to WCGF inclusion when diets were offered at restricted feed intake during the growing phase.

TABLE 4: DRY MATTER INTAKE AND DIGESTIBILITIES OF NUTRIENTS BY BEEF HEIFERS AS AFFECTED BY LEVEL OF WET CORN GLUTEN FEED IN DIETS OFFERED AT TWO LEVELS OF FEED INTAKE DURING GROWING OR AD LIBITUM DURING FINISHING

Item	Treatments ¹						SE
	1	2	3	4	5	6	
	LIB 25	LIB 50	RES 0	RES 25	RES 50	RES 75	
DM intake ^{2,3}	----- kg/d -----						
Growing phase	6.82	6.91	6.33	6.25	6.30	6.73	.31
Finishing phase	5.36	5.43	5.80	6.30	5.65	6.41	.43
Digestibility ³	----- % of intake -----						
Growing phase							
DM	49.7	57.1	71.6	63.3	65.8	63.4	7.8
OM	58.1	63.1	74.6	69.8	73.6	70.7	6.9
NDF	31.5	46.6	40.9	47.0	54.4	56.3	11.8
CP	48.9	54.6	64.5	56.2	64.3	66.5	8.0
GE	54.3	59.7	70.0	64.9	70.7	68.7	7.3
Finishing phase							
DM	59.6	62.0	66.4	65.8	58.9	59.3	6.3
OM	65.5	68.9	69.6	70.3	66.0	69.2	5.1
NDF	23.6	43.1	33.4	39.5	44.4	40.6	9.8
CP	57.6	64.7	61.7	64.3	61.1	70.2	5.9
GE	61.5	65.4	64.4	66.4	61.7	66.4	5.8

¹Treatments were levels of wet corn gluten feed (WCGF; as a percentage of DM) in diets that were offered ad libitum (LIB) or at restricted (RES) feed intake during the growing phase.

²Daily DMI represent the last 4 d of each 12-d period in which heifers were fed Cr (in the form of Cr₂O₃) as a digestibility marker.

³Means were compared by orthogonal contrasts [contrasts were: 1) treatment 1 vs treatment 2 (diets containing WCGF; offered ad libitum during the growing phase), 2) treatment 3 vs treatments 4, 5, and 6 (diet containing no WCGF vs those containing WCGF; offered at restricted feed intake during the growing phase), and both 3) linear and quadratic responses to WCGF inclusion when diets were offered at restricted feed intake during the growing phase] and no differences ($P > .2$) were detected.

TABLE 5: CARCASS CHARACTERISTICS OF BEEF HEIFERS AS AFFECTED BY LEVEL OF WET CORN GLUTEN FEED IN DIETS OFFERED AT TWO LEVELS OF FEED INTAKE DURING GROWING OR AD LIBITUM DURING FINISHING

Item	Treatments ¹												Contrasts ² (<i>P</i> =)				
	1		2		3		4		5		6		SE	1	2	3	4
	LIB	25	LIB	50	RES	0	RES	25	RES	50	RES	75					
Hot carcass wt., kg	279.9	279.9	279.0	279.0	275.9	275.9	288.4	288.4	277.5	277.5	270.2	270.2	4.8	.9	.6	.21	.05
Dressing percentage	62.2	62.2	62.4	62.4	62.3	62.3	62.9	62.9	62.1	62.1	62.3	62.3	.4	.6	.7	.7	.6
Longissimus muscle area, cm ²	81.4	81.4	79.2	79.2	79.0	79.0	80.2	80.2	78.4	78.4	79.4	79.4	2.1	.5	.9	.9	.9
Backfat thickness ³ , cm	1.06	1.06	1.13	1.13	1.40	1.40	1.21	1.21	1.08	1.08	1.16	1.16	.08	.5	.01	.04	.11
Kidney, pelvic, and heart fat, %	2.52	2.52	2.55	2.55	2.54	2.54	2.49	2.49	2.72	2.72	2.44	2.44	.08	.8	.9	.9	.19
Marbling score, degree ⁴	1035	1035	1052	1052	1066	1066	1052	1052	1061	1061	1006	1006	17	.5	.19	.04	.3
Yield grade ⁵	2.35	2.35	2.53	2.53	2.78	2.78	2.62	2.62	2.54	2.54	2.46	2.46	.15	.4	.16	.13	.8
USDA choice carcass, %	66.9	66.9	70.1	70.1	82.5	82.5	78.2	78.2	61.4	61.4	54.3	54.3	10.3	.8	.14	.04	.9
Liver abscess, %	8.1	8.1	8.1	8.1	35.9	35.9	36.7	36.7	12.3	12.3	8.2	8.2	9.7	.9	.14	.02	.8

¹Treatments were levels of wet corn gluten feed (WCGF; as a percentage of DM) in diets that were offered ad libitum (LIB) or at restricted (RES) feed intake during the growing phase.

²Contrasts were 1) treatment 1 vs treatment 2 (diets containing WCGF; offered ad libitum during the growing phase), 2) treatment 3 vs treatments 4, 5, and 6 (diet containing no WCGF vs those containing WCGF; offered at restricted feed intake during the growing phase), and both 3) linear and quadratic responses to WCGF inclusion when diets were offered at restricted feed intake during the growing phase.

³Subcutaneous fat over the longissimus muscle at the 12th rib.

⁴1000 = choice⁻, 1100 = choice⁰, 1200 = choice⁺.

⁵Yield grade was calculated as 2.5 + (2.5 × backfat thickness) + (.0038 × hot carcass weight) + (.2 × kidney, pelvic, and heart fat) - (.32 × longissimus muscle area).

INFLUENCE OF SOURCE OF DIETARY PROTEIN AND LEVEL OF RUMINALLY PROTECTED LYSINE AND METHIONINE ON FEEDLOT PERFORMANCE AND CARCASS CHARACTERISTICS OF HOLSTEIN STEERS

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SUMMARY

The objective was to determine the effects of source of dietary CP and level of ruminally protected lysine and methionine (RPLM) on feedlot performance and carcass characteristics of Holstein steers fed high concentrate diets during a growing-finishing trial. A total of 168 Holstein steers were used in a completely randomized design experiment. Treatments were arranged as a 2×4 factorial. The main factors were two sources of dietary CP and four levels of RPLM. The sources of dietary CP were soybean meal (SBM) or SBM and urea (SBM-U). Urea-N replaced 50% of SBM-N in the SBM-U diet. The levels of RPLM were 0, 5, 10, and 15 g per steer daily. Steers were subjected to the eight dietary treatments for 266 days. There were three replications (pens)/treatment. Diets contained 13% CP (DM basis) and were offered ad libitum. No interactions ($P > .10$) between source of dietary CP and level of RPLM were observed for feedlot performance or carcass characteristics. Feedlot performance showed an advantage ($P < .10$) to feeding SBM during the first 84 d of the trial and an advantage to feeding SBM-U during the last 98 d of the trial. However, feedlot performance for the whole trial and carcass characteristics (except for backfat thickness) were not affected ($P > .10$) by the source of dietary CP. Supplementation of diets with RPLM did not improve ($P > .10$) feedlot performance or carcass characteristics. Results suggest a cost advantage for replacing 50% of SBM-N with that from urea in high corn diets without negative effects on feedlot performance or carcass characteristics of growing-finishing Holstein steers with extended feeding periods (266 d). These types of diets appear to meet the amino acid requirements with no need for protected lysine and methionine.

INTRODUCTION

Results of estimating amino acid supply and requirements (Komarek et al., 1983) and N retention (Chalupa and Chandler, 1975; Richardson and Hatfield, 1978) indicated that lysine and methionine are usually the first limiting amino acids for growing cattle. Understanding of such limitations in requirements can be assessed by feeding amino acids that are protected from ruminal degradation and are available for digestion and absorption in the small intestine. Such protected amino acids can complement amino acids leaving the ruminal fermentation (from microbial protein and undegraded feed protein). In this trial, Holstein steers were fed a high concentrate (based on corn) diet during growing and finishing phases to evaluate the efficacy of RPLM when supplemental CP was from preformed amino acids (SBM) or from preformed amino acids and nonprotein N (SBM-U).

MATERIALS AND METHODS

Steers and Diets. One hundred and sixty-eight Holstein steers were used in a completely randomized design experiment. Treatments were arranged as a 2×4 factorial. The main factors were two sources of dietary CP and four levels of ruminally protected lysine and methionine (RPLM). The sources of dietary CP were soybean meal (SBM) or SBM and urea (SBM-U). The levels of RPLM were 0, 5, 10, and 15 g steer⁻¹ d⁻¹. Steers were subjected to the eight dietary treatments for a 266-d growing-finishing trial. There were three replications (pens)/treatment. Two high concentrate diets (Table 1) containing 13% CP (DM basis) were offered ad libitum. These diets were similar in composition except for their protein supplements (Table 2). These supplements contained SBM or SBM and urea (50% of CP from SBM was replaced with urea). Either SBM alone or SBM and urea provided 40% of total dietary CP. The diets were formulated to contain 1.2% Ca, .5% P, .8% K, .30% trace mineralized salt, and to provide daily intakes of 30,000 IU of vitamin A. These nutrients were balanced to meet or exceed the recommended requirements (NRC, 1984) for large-frame steers. Diets were fed fresh once daily and the amounts (i.e., 0, 5, 10, and 15 g per steer daily) of RPLM (Smartamine ML®; Rhône-Poulenc Animal Nutrition, Atlanta, GA) were added to the dietary ingredients while mixing diets for each pen. This product contains 50% L-lysine and 15% DL-methionine which are encapsulated in a pH-sensitive coating (poly 2vinylpyridine-co-styrene). Six steers were removed from the trial for reasons not related to treatment. All steers were implanted with Revalor-S on d 1 and d 112 of the feeding period.

Analytical Procedures. Samples of feeds were analyzed for concentrations of DM, OM, and Kjeldahl-N (AOAC, 1984), and also NDF (Jeraci et al., 1988).

Carcass Characteristics. Steers were slaughtered at a commercial packing plant and their carcasses were evaluated by University of Illinois personnel at 24 h postmortem.

Statistical Analyses. This trial was analyzed as a completely randomized design experiment (Steel and Torrie, 1980) according to the GLM procedures of SAS (1985). Because treatments were arranged as a 2×4 factorial, the sum squares for the treatments in the GLM model were separated into source of dietary CP, level of RPLM, and the source of dietary CP \times level of RPLM interaction. Pen was the experimental unit for the performance data and steer was the experimental unit for the carcass data. Because interactions were not detected ($P > .10$), means for source of dietary CP were compared by the LSD procedure (Fisher, 1949) whereas orthogonal contrasts (Steel and Torrie, 1980) were used to test for linear, quadratic, and cubic effects of RPLM supplementation.

RESULTS AND DISCUSSION

No interactions ($P > .1$) between source of dietary CP and level of RPLM were observed for feedlot performance or carcass characteristics. Therefore, results of the main effects are presented.

Feedlot Performance. The influence of source of dietary CP and levels of RPLM on growth performance of steers is shown in Table 3. Steers responded differently to source of dietary CP during different growth periods. During the first 84 d of the trial, steers fed diets containing SBM had 7% faster ($P < .10$) gain and they were 5% more ($P < .10$) efficient in utilizing feed than those fed diets containing SBM-U. During the second 84-d of the trial, however, feedlot performance was similar ($P > .10$) for steers fed diets containing either source of dietary CP. During the last 98-d of the trial, the advantage was obvious to feeding SBM-U. Steers fed diets containing SBM-U had 10% faster ($P < .10$) gain and 8% better ($P < .10$) gain/feed than those fed diets containing SBM. The cumulative (266 d) performance showed that source of dietary CP did not alter ($P > .10$) ADG, DMI, or gain/feed. This observation indicates that 50% of CP in SBM can be replaced by a cheaper source of CP (i.e., urea) without compromising feedlot performance of Holstein steers when fed high concentrate diets during growing and finishing phases.

Supplementation of diets with increasing levels of RPLM did not affect ($P > .10$) ADG during any of the three growth periods of the trial. However, DMI and gain/feed showed cubic ($P < .10$) responses to increasing dietary level of RPLM. Supplementation of RPLM at the 10 g/d level was successful in improving gain/feed by 12% during the last 98-d of the trial.

The cumulative (266 d) performance showed a quadratic ($P < .10$) gain response to RPLM supplementation. Steers fed either 5 or 10 g/d of RPLM had similar final weights and similar ADG which were 3 to 4% higher than those fed diets without RPLM supplementation. Cubic responses to RPLM were also detected for DMI and gain/feed, with steers fed diets containing 10 g of RPLM having the highest gain/feed ratio. The results are interpreted to suggest that supplementation of high concentrate diets with graded levels of RPLM will not improve ($P > .10$) feedlot performance of Holstein steers fed for extended periods (266 d).

Carcass Characteristics. The influence of source of dietary CP and levels of RPLM on of carcass characteristics of steers is shown in Table 4. Incidence of liver abscess was not detected (no livers were condemned) indicating that Holstein steers were well adapted to the high concentrate diets during the 266 d period.

Source of dietary CP did not affect ($P > .10$) most of the carcass characteristics. The only exception was noted for backfat thickness. Steers fed diets containing SBM-U had 12% thinner ($P < .10$) backfat than those fed diets containing SBM. This observation suggests another advantage to replacing 50% of SBM-N with urea. In agreement with data in Table 3, no advantage was observed ($P > .10$) in carcass characteristics when high corn diets were supplemented with RPLM at levels up to 15 g/d. It is noteworthy that 85% of these steers graded choice after receiving two Revalor-S implants. The fact that the second implant was given 154 d before the end of the trial, prevented the depression in quality grade that has been observed with shorter periods between implanting and slaughter.

CONCLUSIONS

Results of feeding Holstein steers high concentrate diets (based on corn) for a 266-d growing-finishing trial suggested that 50% of CP in the SBM diet (13% CP) can be replaced with a cheaper source of CP such as urea, without compromising feedlot performance or carcass characteristics. Supplementation of these diets with levels of RPLM up to 15 g/d did not improve feedlot performance or carcass characteristics. The absence of response to RPLM may be attributed to the high corn in the diets and extended feeding period. Hussein and Jordan (1991) showed that high corn diets can contribute a proportion of undegraded CP that can complement bacterial protein synthesized in the rumen.

REFERENCES

- AOAC. 1984. Official Methods of Analysis (14th Ed.). Association of Official Analytical Chemists, Washington, DC.
- Chalupa, W., and J. E. Chandler. 1975. Methionine and lysine nutrition of growing cattle. *J. Anim. Sci.* 41:394. (Abstr.).
- Fisher, R. A. 1949. *The Design of Experiments*. Oliver and Boyd Ltd., Edinburgh.
- Hussein, H. S., and R. M. Jordan. 1991. Fish meal as a protein supplement in finishing lamb diets. *J. Anim. Sci.* 69:2115.
- Jeraci, J. L., T. Hernandez, J. B. Robinson, and P. J. Van Soest. 1988. New and improved procedure for neutral-detergent fiber. *J. Anim. Sci.* 66(Suppl. 1):351 (Abstr.).
- Komarek, R. J., R. A. Jandzinski, and S. R. Ames. 1983. Effect of diet upon the postruminal supplies of amino acids in the steer. *J. Anim. Sci.* 57(Suppl.1):447. (Abstr.).
- NRC. 1984. *Nutrient Requirements of Beef Cattle* (6th Ed.). National Academy Press, Washington, DC.
- Richardson, C. R., and E. E. Hatfield. 1978. The limiting amino acids in growing cattle. *J. Anim. Sci.* 46:740.
- SAS. 1985. *SAS User's Guide: Statistics* (version 5 Ed.). SAS Inst. Inc., Cary, NC.
- Steel, R. G. D., and J. H. Torrie. 1980. *Principles and Procedures of Statistics: A Biometrical Approach* (2nd Ed.). McGraw-Hill Publishing Co., New York.

TABLE 1: INGREDIENT AND CHEMICAL COMPOSITIONS OF DIETS FED TO HOLSTEIN STEERS

Item	Diets ¹	
	SBM	SBM-U
	----- % of DM -----	
Ingredient composition		
Whole shelled corn	71	71
Protein supplement ²	15	15
Corn silage	10	10
Condensed distillers solubles	4	4
Chemical composition		
OM	94.8	97.7
CP	13.1	13.2
NDF	14.4	14.1

¹Containing soybean meal (SBM) or SBM and urea (SBM-U).

²Containing 35.9% CP on a DM basis (all from SBM or 50% from SBM and 50% from urea and ground corn; Table 2).

TABLE 2: INGREDIENT COMPOSITION OF PROTEIN SUPPLEMENTS FED TO HOLSTEIN STEERS

Ingredient	Protein supplement ¹	
	SBM	SBM-U
	----- % of DM -----	
Soybean meal	67.6	33.8
Urea	--	5.33
Dicalcium phosphate	5.95	6.75
Limestone	14.57	14.39
Potassium bicarbonate	1.15	2.62
Condensed distillers solubles	3.0	3.0
Trace mineralized salt ²	2.67	2.67
Rumensin-80 ³	.14	.14
Tylan-40 ⁴	.08	.08
Thiamin	.3	.3
Vitamin premix ⁵	.2	.2
Ground corn	4.34	30.72

¹Containing soybean meal (SBM) or SBM and urea (SBM-U).

²Composition (g/100 g): NaCl (97 to 99), Zn (> .35), Fe (> .2), Mn (> .18), Cu (> .035), I (> .01), Se (> .009), Co (> .006).

³Contains 176 g monensin/kg.

⁴Contains 88 g tylosin/kg.

⁵Composition (per gram): vitamin A (3,300 IU), vitamin D3 (330 IU), vitamin E (44 IU), vitamin K (2.2 mg), vitamin B12 (.0176 mg), riboflavin (4.4 mg), D-pantothenic acid (12.1 mg), niacin (16.5), choline chloride (165.0 mg).

TABLE 3: FEEDLOT PERFORMANCE OF HOLSTEIN STEERS AS AFFECTED BY SOURCE OF CRUDE PROTEIN IN THE DIETS¹ AND LEVELS OF RUMINALLY PROTECTED LYSINE AND METHIONINE SUPPLEMENTATION

Item	Source of CP ²			Levels of RPLM ³				SE
	SBM	SBM-U	SE	0	5	10	15	
No. of pens	12	12		6	6	6	6	
No. of steers	81	81		41	40	39	42	
Initial wt, kg	183.1	182.3	1.3	182.9	183.8	182.6	181.3	1.8
d 1 to d 84:								
ADG, kg ⁴	1.84	1.72	.03	1.74	1.83	1.77	1.78	.04
DMI, kg/d ⁵	7.22	7.09	.08	6.83	7.39	7.01	7.39	.11
Gain/feed ⁵	.255	.242	.003	.255	.247	.251	.241	.004
d 85 to d 168:								
ADG, kg	1.69	1.64	.02	1.63	1.68	1.68	1.66	.03
DMI, kg/d ⁵	8.69	8.58	.10	8.33	9.09	8.32	8.78	.24
Gain/feed ⁵	.194	.192	.003	.196	.184	.203	.189	.004
d 169 to d 266:								
ADG, kg ⁴	.72	.79	.03	.73	.76	.80	.73	.04
DMI, kg/d ⁵	8.71	8.73	.13	8.61	9.20	8.35	8.73	.24
Gain/feed ^{4,5}	.083	.090	.002	.085	.082	.095	.083	.004
The whole trial (266 d):								
Final wt, kg ⁶	550.0	541.3	4.7	538.2	552.5	550.6	541.3	6.7
ADG, kg ⁶	1.38	1.35	.02	1.34	1.39	1.38	1.35	.02
DMI, kg/d ⁵	8.23	8.17	.09	7.96	8.59	7.92	8.32	.13
Gain/feed ⁵	.168	.165	.001	.168	.161	.175	.163	.002

¹Steers were fed high concentrate (90% of DM) diets containing 13.2% CP during the growing-finishing trial.

²Dietary sources of CP were soybean meal (SBM) or SBM and urea (SBM-U).

³Levels of ruminally protected lysine and methionine (RPLM) were 0, 5, 10, or 15 g of Smartamine ML[®] per steer daily.

⁴Effect of dietary source of CP ($P < .10$).

⁵Cubic ($P < .10$) response to RPLM supplementation.

⁶Quadratic ($P < .10$) response to RPLM supplementation.

TABLE 4: CARCASS CHARACTERISTICS OF HOLSTEIN STEERS AS AFFECTED BY SOURCE OF CRUDE PROTEIN IN THE DIETS¹ AND LEVEL OF RUMINALLY PROTECTED LYSINE AND METHIONINE SUPPLEMENTATION

Item	Source of CP ²			Levels of RPLM ³				
	SBM	SBM-U	SE	0	5	10	15	SE
Hot carcass wt., kg	315.0	309.5	3.0	309.7	314.2	315.2	309.8	4.4
Dressing percentage	57.4	57.4	.3	57.6	57.0	57.6	57.3	.5
Longissimus muscle area, cm ²	71.9	71.7	.8	71.8	71.8	72.2	71.3	1.2
Backfat thickness, cm ⁴	.69	.61	.03	.67	.64	.64	.65	.03
Kidney, pelvic, and heart fat, %	3.61	3.64	.10	3.75	3.54	3.66	3.56	.14
Marbling score, degree ⁵	1072	1056	10	1058	1088	1059	1049	15
Yield grade ⁶	2.98	2.86	.05	2.94	2.91	2.92	2.90	.07
USDA choice carcass, %	82.8	87.2	4.2	85.5	92.2	83.6	78.6	5.6

¹Steers were fed high concentrate (90% of DM) diets containing 13.2% CP during the growing-finishing trial.

²Dietary sources of CP were soybean meal (SBM) or SBM and urea (SBM-U).

³Levels of ruminally protected lysine and methionine (RPLM) were 0, 5, 10, or 15 g of Smartamine ML® steer⁻¹ d⁻¹.

⁴Effect of dietary source of CP ($P < .10$).

⁵1000 = choice⁰, 1200 = choice⁺.

⁶Yield grade was calculated as $2.5 + (2.5 \times \text{backfat thickness}) + (.0038 \times \text{hot carcass weight}) + (.2 \times \text{kidney, pelvic, and heart fat}) - (.32 \times \text{longissimus muscle area})$.

EFFECTS OF ZINC AND CALCIUM SUPPLEMENTATION ON PERFORMANCE, CARCASS TRAITS, AND HOOF STRENGTH IN FEEDLOT HEIFERS

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SUMMARY

One hundred forty-two yearling feedlot heifers were weighed and randomly allotted to one of twelve pens. The trial used a 2 X 2 X 3 factorial arrangement of treatments to evaluate the effects of two supplemental Zn sources (zinc sulfate and zinc proteinate) fed at two levels (180 or 360 mg/d) in combination with three levels of dietary Ca (.30, .65, and 1.00%). Heifers were weighed at 28-d intervals and terminated after either 83 or 132 d on feed, dependent on market readiness. Heifers were slaughtered at a commercial packing plant where hoof and carcass data were collected. Hooves were mechanically removed from the carcass, identified, and placed in cold (0° C) storage. Within 2 d, the bottom of each hoof toe was planed, and a cross-sectional 5 mm (.2 in) thick slice obtained for shear analysis using an MTS material testing machine. Four shears were conducted on each animal or experimental unit and exact hoof thickness was used as a covariate in statistical analyses. There were no statistical differences in carcass traits due to treatment effects, although heifers supplemented with 360 mg of Zn had a slight, numerical advantage in marbling score. Hooves of heifers that remained on feed for 132 d were stronger, having steeper slopes of elastic and permanent deformation and required 23 kg ($P < .01$) more maximal force to complete shearing than those fed 83 d. A Zn type by days on feed interaction was significant ($P < .07$) as ZnSO₄ and zinc proteinate supplemented heifers had similar hoof strength values at 83 d, but the ZnSO₄ treated hooves required 8.8 kg more force after 132 d on test. Increased levels of Zn and Ca, however, did not improve hoof strength. Overall, it does not appear that the addition of Zn or Ca in excess of the NRC requirements, met by the basal diet, had any positive affect on performance, carcass, or hoof strength traits.

INTRODUCTION

Performance, health, and nutrition are highly interrelated. For example, foot rot is a major cause of lameness in beef and dairy cattle. Although bacteria which cause foot rot cannot penetrate the intact hoof surface or skin between the toes, *Fusobacterium necrophorum* and *Bacteroides melaninogenicus* (Berg and Loan, 1975) may initiate infection when provided a port of entry. Zinc (Zn), an essential trace mineral, is necessary for the keratinization or proper hardening of epithelial tissues (Mills et al., 1967), and plays a role during activation of the immune response (Klasing, 1988).

Yet only 5 to 40% of Zn intake is actually absorbed and transported throughout the body from the small intestine (Church and Pond, 1988). Absorption of metal ions (minerals) requires chelation of the mineral with natural ligands produced by digestion of feed components. However, many natural ligands, such as phytate or inositol hexaphosphate, will actually produce insoluble complexes with many cations such as

calcium (Ca) and Zn (O'Dell, 1983) rendering them unavailable to the animal. However, commercially complexed or chelated minerals are not subjected to the natural random chelation process of digestion, and have greater bioavailability. Using zinc sulfate (ZnSO₄) as a standard, zinc oxide (ZnO) has only 61% bioavailability, whereas zinc-methionine (ZnMet) is 206% bioavailable (Wedekind et al., 1992).

However, metal amino acid chelates can be very expensive relative to ZnSO₄ (Nelson). Metal proteinate complexes offer an opportunity for increased absorption and utilization of the mineral compared to inorganic sources and decreased cost, relative to the amino acid chelate. Lardy et al. (1992) concluded that zinc proteinate (ZnProt) complexes were retained to a greater ($P < .05$) extent than ZnO.

Furthermore, it is well established that Ca is important for proper bone formation, and may be important for maximal hoof strength and integrity. The NRC (1984) requirement of growing and finishing feedlot cattle is approximately .30%, dependent on weight and performance. However, there has been a trend to increase the quantity of Ca in the diet to improve post-ruminal starch digestion (Wheeler, 1980), but excess Ca can decrease Zn absorption and utilization (NRC, 1980), potentially increasing the Zn requirement to maintain maximal hoof strength and integrity. Thus, the current study was undertaken to evaluate the effect of ZnProt vs. ZnSO₄ fed at either 180 or 360 mg/hd·d⁻¹ in combination with three levels of dietary Ca (.3, .65, and 1.00%) on carcass and hoof strength characteristics of feedlot heifers.

MATERIALS AND METHODS

One hundred forty-two yearling feedlot heifers were weighed and randomly allotted to one of twelve pens located within a 3-sided confinement structure with concrete, slotted floors. Interim weights were taken every 28 d, and termination weights, following a 12-h shrink, were taken after 83 or 132 d on feed.

The trial used a 2 X 2 X 3 factorial arrangement of treatments to evaluate the effects of different supplemental Zn sources (ZnProt and ZnSO₄), levels of Zn supplementation (180 and 360 mg/d), and levels of dietary Ca (.30, .65, and 1.00%) on carcass traits and hoof strength characteristics. The basal diet (10% corn silage, 7% corn distillers solubles, 73% high-moisture corn, and 10% supplement (Table 1) on a DM basis) supplied 12.1% crude protein, .30% Ca, and 69 ppm (mg/kg) of Zn. A supplemental ZnProt or ZnSO₄ premix calculated to possess 400 mg/kg (180 mg/lb, as-fed basis) was top-dressed at the rate of .45 or .90 kg/animal (1 or 2 lb/animal, as-fed basis) depending on the Zn level desired. To increase the Ca level of the basal diet from .30% to .65 and 1.00%, a corn-limestone mixture (80.3% corn and 19.7% limestone, DM basis) replaced 5 or 10% of the high-moisture corn in the basal diet. Mineral analyses (Forage Testing Laboratory, Northeast DHIA, Ithaca, NY) confirmed that actual Zn and Ca levels of the feed were within a normal, expected range of those calculated.

Heifers were terminated after 83 or 132 d on feed, dependent upon market readiness, transported approximately 320 km (200 mi) to a commercial packing plant where hoof samples and carcass data were collected. Twenty-four h post-mortem, carcass yield

and quality traits were evaluated by trained University of Illinois personnel. Yield factors included fat thickness at the 12th rib, longissimus muscle area, hot carcass weight, and percentage of kidney, pelvic, and heart fat. From these factors, a final yield grade was calculated. Marbling scores were also evaluated as a measure of carcass quality.

Upon slaughter, front hooves from each animal were mechanically removed from the carcass, identified and individually bagged, packed with dry ice, transported to the university, and placed in cold (0° C) storage. Within 2 d, the bottom of each toe (two toes per hoof) was planed, and a cross-sectional 5 mm (.2 in) thick slice obtained for shear analysis. Exact hoof thickness was measured through use of a micrometer and used as a covariate for statistical analysis of hoof strength. To test hoof strength, an MTS material testing machine was outfitted with a shear apparatus to measure the force required to shear a 1.3 cm (.5 in) diameter hole through the bottom side of the hoof. Data collected from the shearing of hoof slices included the maximum force required for penetration, slope of elastic deformation, and slope of permanent deformation. The slope of elastic deformation, for which no physical damage has yet occurred, was determined as the force required per mm of thickness through 2 mm of compression. The slope of permanent deformation was determined as the force required per mm of thickness for actual shearing of the sample.

Since the 2 X 2 X 3 factorial arrangement of treatments required the use of 12 pens, it was not possible to statistically analyze differences in performance due to treatment. To analyze both carcass and hoof data, the individual animal served as the experimental unit where a protected F-test (SAS, 1988) was used to assess differences in treatment means. Hoof thickness was also used as a covariate for analysis of hoof strength indices.

RESULTS AND DISCUSSION

Because of the large number of interactive treatments, the experiment was not replicated, and thus performance (using pen as an experimental unit) could not be statistically analyzed. However, the arithmetic means of each pen are shown in Table 2. Heifers had an average daily gain of 1.54 kg/d (3.40 lbs/d), consumed 7.51 kg (16.56 lbs) of DM per d, and had an average gain to feed ratio of .205 (4.88 units of DM required per unit of gain). There appeared to be no effect of the dietary Zn or Ca treatments on performance. Similarly, most studies supplying 360 mg of supplemental Zn as ZnMet have not detected significant performance responses (Nelson).

The main effects of the supplemental Zn treatments on carcass traits are shown in Tables 3 and 4. Interactions between Zn type, Zn level, and Ca level of the diet were not significant and are not shown. Previous research (Green et al., 1988) had indicated that supplemental Zn levels (360 mg) similar to those used in the current study as ZnMet improved ($P < .05$) marbling scores and carcass quality grades as compared to controls or the same level of Zn fed as ZnO. Rust (1985) also showed that supplemental ZnMet tended to improve ($P < .10$) quality grades, but estimated that a price differential of \$5-7/cwt between select and choice carcasses was needed to justify the cost of ZnMet. In contrast, other studies (Carrica et al., 1986; Neel et al.,

1986 Martin et al., 1987) show that carcass traits were not affected by Zn supplementation. This study further revealed no effect of Zn supplemental type or level on carcass traits. Although the 360 mg supplemental Zn level showed a slight, numerical advantage in marbling score, despite those carcasses being .07 cm leaner. Also no differences in carcass yield or quality were observed due to the different Ca levels fed to heifers.

The primary objective of the study was to evaluate the effects of the Zn and Ca supplementation on indices of hoof strength. Approximately one-half of the heifers were determined to be market ready, and slaughtered after 83 d on feed. The remaining heifers were slaughtered after 132 d. The effect of supplemental feeding time on hoof strength characteristics is shown in Table 6. Hooves, from heifers fed the additional 49 d, required 23 kg more ($P < .01$) maximal force to complete shearing, and the slope of elastic and permanent deformation was 14.2 and 21.1% steeper, respectively, than those fed for only 83 d. Reiling et al. (1992), had also found that hooves of yearling and two year old heifers required 24.3 kg more ($P < .05$) shearing force when 180 mg of supplemental Zn was fed for 75 d as compared to only 45 d. In the current study, however, an interaction was present ($P < .07$) between Zn supplemental type and days on test as shown in Figure 1. At 83 d, ZnSO₄ and ZnProt treated hooves required 124.2 and 127.3 kg maximal force, respectively, but after 132 d on feed, the ZnSO₄ hooves required 8.8 kg more force (153.2 vs. 144.4; $P < .05$) than the ZnProt treated hooves. The magnitude of difference becomes greater with length of feeding. Perhaps a potentially faster rate of absorption for ZnProt is more advantageous during shorter feeding periods. As time on feed increases, the accumulation of inorganic mineral offsets the faster absorption rate of the commercially complexed form. Other indices of hoof strength further showed no difference in Zn supplemental type (Table 7). There also appeared to be no advantage to supplementing 360 mg vs. 180 mg of Zn (Table 8). Hoof strength characteristics were similar due to level of Zn. Figure 2 reveals an interaction between Zn type and Zn level on maximal shearing force. The ZnProt supplemented hooves were weakest when fed the 180 mg level, but strongest when fed the 360 mg level. This is contradictory to what one might expect since the ZnProt should be more easily absorbed, and may simply be an artifact of the data. Also, no differences or interactions were observed due to Ca level (Table 9), although Ca has been known to negatively affect Zn absorption (NRC, 1980).

IMPLICATIONS

From this study, it does not appear that the addition of Zn or Ca in excess of the NRC requirements will have any affect upon performance, carcass traits, or hoof strength and integrity. At the levels fed in this experiment, there was no interaction of the Zn and Ca supplementation.

LITERATURE CITED

- Berg, J. N. and R. W. Loan. 1975. *Fusobacterium necrophorum* and *Bacteroides melaninogenicus* as etiologic agents of foot rot in cattle. *Am. J. Vet. Res.* 36:1115.
- Carrica, J. M., R. T. Brandt, and R. W. Lee. 1986. Impact of zinc methionine on feedlot performance and carcass merit of medium and large framed steers. *J. Anim. Sci.* 63(Suppl. 1):450 (Abstr.).
- Church, D. C. and W. G. Pond. 1988. *Basic Animal Nutrition and Feeding* (3rd Ed.). John Wiley and Sons, New York, NY.
- Green L. W., N. K. Chirase, D. K. Lunt, G. T. Schelling, and F. M. Byers. 1988. Performance and carcass characteristics of steers fed zinc oxide and zinc methionine. *J. Anim. Sci.* 66:1818.
- Klasing, K. C. 1988. Nutritional aspects of leukocytic cytokines. *J. Nutr.* 118:1436.
- Lardy, G. P., M. S. Kerley, and J. A. Paterson. 1992. Retention of chelated metal proteinates by lambs. *J. Anim. Sci.* 70(Suppl. 1):314 (Abstr.).
- Martin, J. J., C. A. Strasia, D. R. Gill, R. A. Hicks, K. Ridenour, G. Dolezal, and F. N. Owens. 1987. Effect of zinc methionine on live performance and carcass merit of feedlot steers. *J. Anim. Sci.* 65(Suppl. 1):500 (Abstr.).
- Mills, C. F., A. C. Dalgarno, R. B. Williams, and J. Quarterman. 1967. Zinc deficiency and the zinc requirements of calves and lambs. *Br. J. Nutr.* 21:751.
- Moore, C. L., P. M. Walker, J. R. Winter, M. A. Jones, and J. W. Webb. 1989. Zinc methionine supplementation for dairy cows. *Transactions of the Illinois Academy of Science.* 82:99.
- Nelson, J. Sources and application of chelates and complexes in the liquid feed industry. *Liquid Feed Symposium.*
- Neel, J. P., H. E. Kiesling, and G. P. Lofgreen. 1986. Effects of zinc methionine supplementation on feedlot performance and carcass variables. *J. Anim. Sci.* 63(Suppl. 1):450 (Abstr.).
- NRC. 1980. *Mineral Tolerance of Domestic Animals.* National Academy of Sciences, Washington, DC.
- NRC. 1984. *Nutrient Requirements of Beef Cattle* (6th Ed.). National Academy Press, Washington, DC.
- O'Dell, B. L. 1983. Bioavailability of essential and toxic trace elements. *Fed. Proc. Fed. Am. Soc. Exp. Biol.* 42:1714.
- Reiling, B. A., L. L. Berger, G. L. Riskowski, and R. E. Rompala. 1992. Effects of zinc proteinate on hoof durability in feedlot heifers. *J. Anim. Sci.* 70(Suppl. 1):313.

- Rust, S. R. 1985. Effects of zinc methionine and grain processing on performance of growing fattening steers. J. Anim. Sci. 61(Suppl. 1):482 (Abstr.).
- Wedekind, K. J., A. E. Hortin, and D. H. Baker. 1992. Methodology for assessing zinc bioavailability: Efficacy estimates for zinc-methionine, zinc sulfate, and zinc oxide. J. Anim. Sci. 70:178.
- Wheeler, W. E. 1980. Effect of limestone buffers on digestibility of complete diets and on performance of dairy cows. J. Dairy Sci. 63:1848.

Table 1. Composition of Supplement (DM basis).

Ingredients	% (DM basis)
Soybean meal	36.89
Limestone	6.67
Trace mineralized salt + Se	3.18
Rumensin 80	.21
Tylan 40	.10
Potassium carbonate	1.06
Urea	10.59
Thiamine	.27
Vitamin A, D, E	.21
Ground corn	40.83

Table 2. Performance of feedlot heifers provided various levels of zinc and calcium supplementation.

Pen	Treatments			ADG (kg/d)	DMI (kg/d)	G:F ratio
	Ca level (%)	Zn level (mg/d)	Zn type ^a			
1	1.00	360	1	1.40	7.63	.183
2	0.65	180	1	1.51	7.45	.204
3	0.30	180	0	1.56	7.17	.217
4	0.65	360	0	1.51	7.62	.199
5	1.00	180	1	1.52	7.60	.200
6	0.30	180	0	1.57	7.68	.205
7	0.30	360	0	1.56	7.52	.208
8	0.65	360	1	1.54	7.40	.208
9	1.00	360	0	1.58	7.36	.215
10	0.30	180	1	1.44	7.60	.189
11	0.65	180	0	1.65	7.58	.217
12	1.00	360	1	1.66	7.53	.221
Average				1.54	7.51	.205

^a0 = ZnSO₄, 1 = Zn proteinate.

Table 3. Effect of supplemental zinc type on carcass traits of feedlot heifers.

Item	ZnSO ₄	Zn Prot	SEM	P <
Hot Carcass weight, kg	275.1	273.5	3.6	.69
Fat thickness, cm	1.11	1.16	.08	.66
Longissimus muscle area, cm ²	75.91	75.01	1.37	.56
Kidney, pelvic, and heart fat, %	2.76	2.63	.08	.17
Yield grade	2.69	2.74	.13	.74
Quality ^a	5.32	5.32	.22	.99

^a4 = slight, 5 = small, and 6 = modest degree of marbling.

Table 4. Effect of supplemental zinc level on carcass traits of feedlot heifers.

Item	180 mg	360 mg	SEM	P <
Hot Carcass weight, kg	275.2	273.4	3.6	.66
Fat thickness, cm	1.17	1.10	.09	.46
Longissimus muscle area, cm ²	75.30	75.62	1.35	.84
Kidney, pelvic, and heart fat, %	2.73	2.66	.08	.39
Yield grade	2.77	2.65	.13	.40
Quality ^a	5.21	5.43	.22	.37

^a4 = slight, 5 = small, and 6 = modest degree of marbling.

Table 5. Effect of supplemental calcium level on carcass traits of feedlot heifers.

Item	.30 %	.65 %	1.00 %	SEM
Hot Carcass weight, kg	274.6	271.8	276.5	5.2
Fat thickness, cm	1.09	1.13	1.18	.13
Longissimus muscle area, cm ²	75.37	74.85	76.16	1.99
Kidney, pelvic, and heart fat, %	2.70	2.69	2.70	.12
Yield grade	2.68	2.71	2.74	.18
Quality ^a	5.18	5.49	5.29	.32

^a4 = slight, 5 = small, and 6 = modest degree of marbling.

Table 6. Effect of supplemental feeding time on hoof strength characteristics of feedlot heifers.

Characteristic	83 d	132 d	SEM	P <
Maximal force, kg	125.75	148.80	2.94	.01
Slope of elastic deformation, kg/mm	14.71	16.80	.42	.01
Slope of permanent deformation, kg/mm	28.72	34.79	.91	.01

Table 7. Effect of zinc type on hoof strength characteristics of feedlot heifers.

Characteristic	ZnSO ₄	ZnProt	SEM	P <
Maximal force, kg	138.71	135.84	2.92	.38
Slope of elastic deformation, kg/mm	15.91	15.60	.41	.49
Slope of permanent deformation, kg/mm	32.49	31.02	.92	.16

Table 8. Effect of zinc level on hoof strength characteristics of feedlot heifers.

Characteristic	180 mg	360 mg	SEM	P <
Maximal force, kg	135.29	139.26	2.91	.22
Slope of elastic deformation, kg/mm	15.67	15.84	.40	.70
Slope of permanent deformation, kg/mm	31.57	31.94	.91	.71

Table 9. Effect of supplemental Calcium level on hoof strength characteristics of feedlot heifers.

Characteristic	.30 %	.65 %	1.00%	SEM
Maximal force, kg	141.17	134.33	136.33	4.22
Slope of elastic deformation, kg/mm	16.06	15.46	15.74	.60
Slope of permanent deformation, kg/mm	33.02	30.19	32.05	1.32

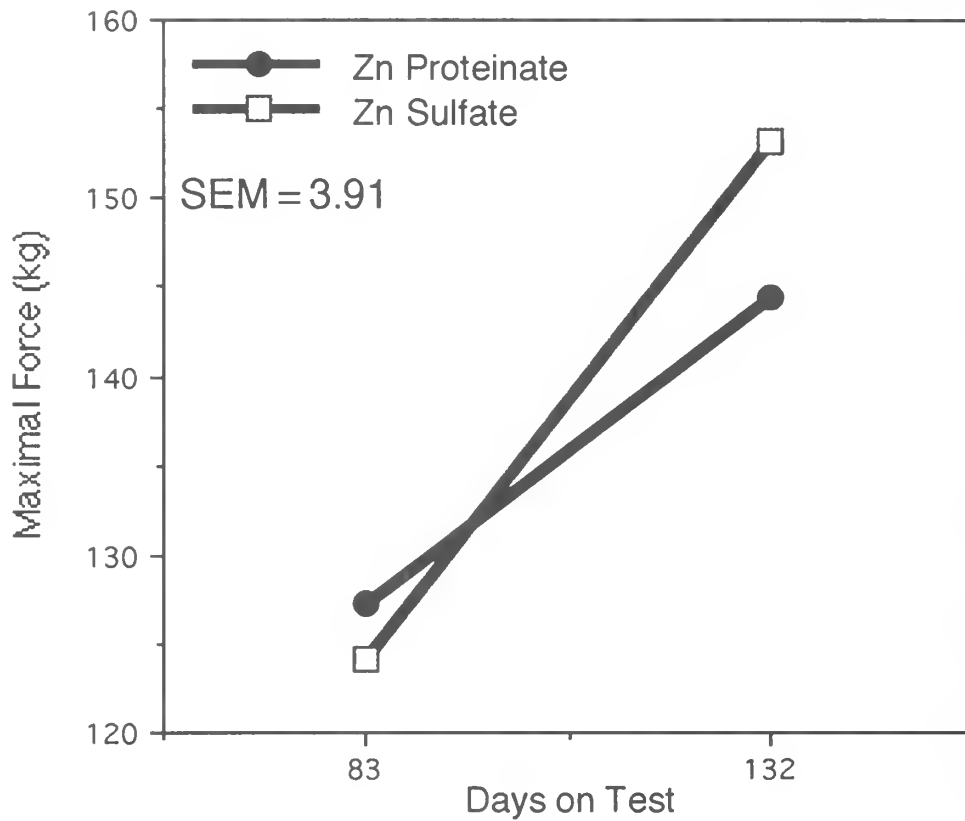


Figure 1. Effect of zinc type and length of supplemental feeding on the maximal force (kg) required to shear a 5 mm thick hoof slice.

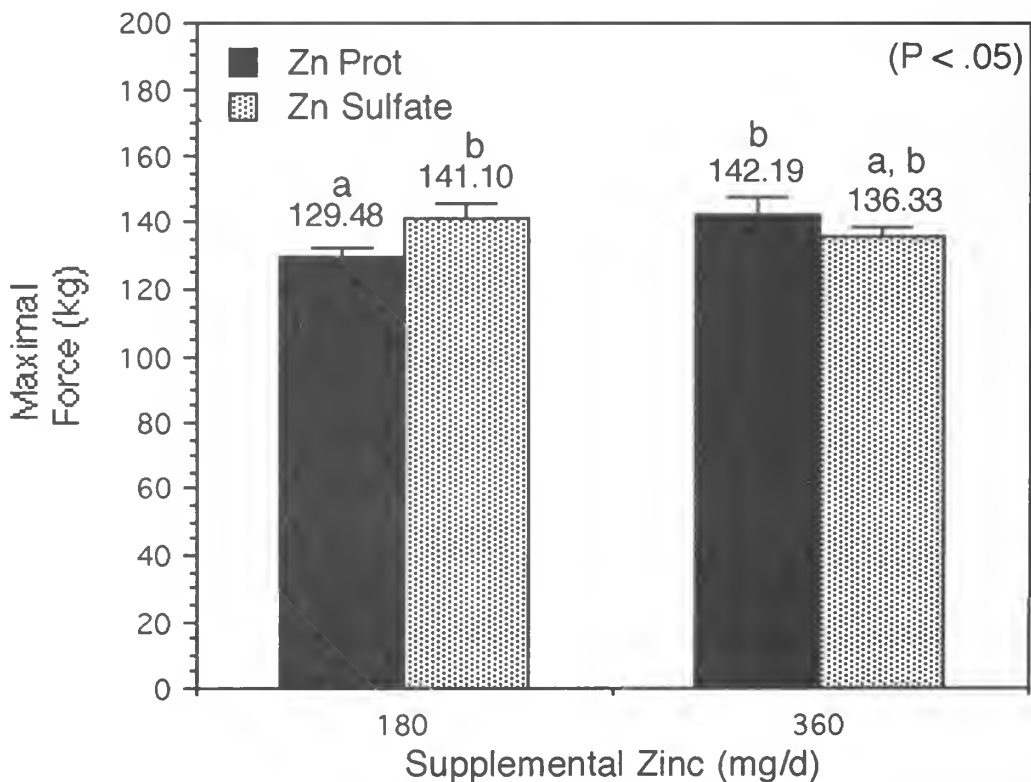


Figure 2. Effect of supplemental zinc level and zinc type on the maximal force (kg) required to shear a 5 mm thick hoof slice.

EFFECTS OF MELENGESTROL ACETATE (MGA) AND SYNOVEX-H IMPLANTS ON GROWTH PERFORMANCE AND CARCASS TRAITS OF OPEN HEIFERS FOLLOWING NORMAL (205 d) WEANING OF THEIR FIRST CALF

B. A. Reiling, L. L. Berger, D. B. Faulkner, and F. A. Ireland

SUMMARY

Fifty-two Angus cross first-calf heifers had their calves removed at approximately 205 d of age (normal weaning) and were placed on a high energy diet to evaluate the effects of melengestrol acetate (MGA) and Synovex-H implants (200 mg testosterone propionate and 20 mg estradiol benzoate) on performance and carcass traits. Full weights were taken on each of two consecutive days, and cattle allotted, randomly, to one of twelve pens. One-half of the heifers were implanted with Synovex-H on d 1 of the trial, and one-half of the implanted and non-implanted animals were fed .40 mg MGA per animal per day throughout the trial. The heifers were weighed every 28 d. Upon conclusion of the study, the animals were again weighed on each of two consecutive days and slaughtered at a commercial packing facility. Twenty-four h postmortem, carcasses were evaluated for quality and yield characteristics. All data was analyzed as a 2 X 2 factorial using the GLM procedure of SAS. Pens were used as the experimental unit for performance data, whereas the individual carcass was used as the experimental unit for analysis of carcass data. Interactions were not significant. Overall, MGA-fed heifers gained 9.2% faster ($P < .05$) than controls. Feed efficiency was similar across treatments. The MGA-fed animals had heavier ($P < .10$) hot carcass weights, larger ($P < .02$) longissimus muscle areas, and were .22 cm leaner ($P < .04$) than control heifers. During the initial 56 d of the trial, Synovex-H implanted heifers gained 13% faster ($P < .09$) than controls, but overall, the implanted animals gained only 4.2% faster and were 4.7% more efficient. Synovex-H had no affect on carcass traits. Only 52% of all carcasses graded choice although marbling scores averaged greater than Small⁰ because of the advanced age of these heifers. Ten of 52 carcasses were classified as C-maturity (hard boned).

INTRODUCTION

Traditional cow-calf management argues that maximal longevity of the female is most efficient as replacement costs are diluted over a larger number of offspring. However, 75 to 80% of nutrients consumed by the cow herd are used for maintenance, and only 20 to 25% for production (Dikeman, 1984). Theoretical calculations by Taylor et al. (1985) have shown that biological efficiency actually increases as the number of calvings per dam decreases because less feed is used for maintenance, and a larger proportion of nutrients are used for the combined functions of reproduction and growth for meat production. Using a single-calf heifer system (Brethour and Jaeger, 1989), heifers are bred to produce one calf followed by feedlot finishing and marketing of the heifer. Provided the heifers are slaughtered by approximately 30 mo of age (Waggoner et al., 1990), a majority should be eligible for the choice grade of beef.

Melengestrol acetate (MGA) is a widely used synthetic progestogen approved in 1968 for use in feedlot heifers (Lauderdale, 1983). Heifers fed MGA do not express estrus or associated physical activity, and thus have improved body weight gain and feed efficiency. An early series of studies involving approximately 10,000 animals found that MGA-fed heifers (.2 to .5 mg/animal per day) gained 10% faster and were 6.5% more efficient than controls (Lauderdale, 1983). Additionally, Synovex-H (200 mg testosterone propionate and 20 mg estradiol benzoate) is widely used in feedlot heifers, and has been shown to improve daily gains and feed efficiency by 8 to 12 and 4 to 5%, respectively (Ray et al., 1969; Goodman et al., 1982). However, these and other studies have evaluated the hormonal growth stimulants using yearling, virgin heifers. Thus, this study was undertaken to evaluate the effects of MGA and Synovex-H implants on the growth and carcass traits of culled, open heifers following normal (205 d) weaning of their first calf.

MATERIALS AND METHODS

A 2 X 2 factorial arrangement of treatments was replicated three times (12 pens) to evaluate the effects of MGA and Synovex-H implants on growth and carcass traits of 52 open heifers following normal weaning (205 d) of their first calf. Full weights were taken on each of two consecutive days as heifers were allotted to one of twelve pens. One-half of the heifers were implanted with Synovex-H on d 1 of the feedlot trial, and one-half of the implanted and non-implanted heifers were fed .40 mg MGA per animal per day throughout the trial. After gradual adjustment, heifers were given ad libitum access to a 90% concentrate, 12.4% CP diet (DM basis) using corn as the primary energy source and late bloom alfalfa hay (15% CP) as a roughage source. The diet was formulated to meet or exceed NRC (1984) requirements for CP, Ca, P, K, trace minerals, and vitamins.

Heifers were weighed at 28-d intervals throughout the 116 d feeding period. Upon termination of the performance study, full weights were again taken on each of two consecutive days, and animals transported approximately 640 km (400 miles) to a commercial packing facility. Twenty-four h postmortem, carcasses were evaluated by trained University of Illinois personnel for quality and yield grade traits.

All data were analyzed by the GLM procedure of SAS (1988) using pen (4-5 animals per pen) as the experimental unit for analysis of performance traits, removing variation due to replicate. Individual carcasses were used as the experimental unit for analysis of carcass traits.

RESULTS AND DISCUSSION

Interactions were not significant, and thus only main effects of MGA and Synovex-H implants are shown. MGA-fed heifers gained 12% faster ($P < .10$) for the first 56 d on trial and 9.2% faster ($P < .05$) overall than control heifers (Table 1). The MGA-fed heifers also tended to consume .9 kg more ($P < .13$) DM/d than controls, but gain:feed ratios were similar across treatment. Still, the MGA-fed heifers were .22 cm fatter ($P < .04$; Table 2) than controls at the time of slaughter. It is widely accepted that efficiency

of gain declines as the percentage of body fat increases and may be a reflection of the similar efficiencies observed. The performance advantages shown herein for feedlot finishing of heifers following the normal removal of their calves are similar to that of yearling, virgin heifers (Lauderdale, 1983; O'Brien et al., 1968). Young et al. (1969) also found that MGA suppressed the onset of estrus when fed to heifers at a level of .4 mg/d, but failed to show any performance advantages. MGA has further failed to show a significant advantage when fed to first-calf heifers following removal of their calf 120 d postpartum (Reiling et al., 1993). That study, however, was conducted during the summer whereas the current study was conducted during the late fall and early winter. Similarly, Ray et al. (1969) reported that growth stimulants, including MGA, were not effective during the summer months, but advantages were observed when administered during the moderate winter months.

Most studies reveal that MGA has little effect on carcass characteristics (Adams et al., 1990; Bloss et al., 1966; Young et al., 1969). In this study (Table 2), the MGA-fed heifers tended to have heavier ($P < .10$) hot carcass weights and a larger ($P < .02$) longissimus muscle area. The MGA-fed heifers were also .22 cm fatter ($P < .04$) at slaughter than controls as these animals did not exhibit the physical activity of estrus nor the associated depressed feed intake. Quality traits did not differ due to treatment, but MGA-fed animals had slightly elevated numerical bone and lean maturity scores. Although marbling scores averaged greater than Small⁰, only 52% of all carcasses graded choice. However, many of these animals were approximately 34 to 36 mo of age at slaughter and 10 of 52 carcasses were classified as C-maturity (hard boned) and were ineligible for the young (select and choice) grades of beef.

The performance response of heifers to the Synovex-H implants is shown in Table 3. During the initial 56 d of the trial, implanted heifers gained 13% faster ($P < .09$) than controls, but overall, the Synovex-H treated animals gained 4.2% faster and were 4.7% more efficient than controls. These responses are less than that reported for yearling feedlot heifers as Adams et al. (1990) found a 12.2 and 8.0% improvement ($P < .01$) in daily gain and feed efficiency, respectively. However, Waggoner et al. (1990) found no performance advantages for Synovex-H implanted single calf heifers in the feedlot following weaning of their first calf. The implant also failed to show a response in mature cows (Faulkner et al., 1990; Jones, 1982).

Synovex-H had no effect on carcass traits (Table 4), including maturity. Previous research had indicated that implanted single calf heifers possessed a greater concentration of calcium in the cartilaginous buttons as compared to non-implanted controls (Waggoner et al., 1990).

IMPLICATIONS

Cow-calf producers have been urged to maximize their productivity through stringent culling of low producing or open cows. Also, the alternative single-calf heifer system requires that females be fed for slaughter following weaning of the calf. Regardless of the system implemented, it appears that MGA, fed at .4 mg/animal per day, will suppress estrus in these sexually mature females increasing their average daily gain and feed efficiency. Implantation of Synovex-H, as shown in other studies, however,

did not greatly improve performance. Carcass traits were not affected by either treatment. Nonetheless, to minimize the presence of C-maturity carcasses and to maximize economic profitability, the heifers need to be slaughtered at an earlier age (30 mo) than in this study.

LITERATURE CITED

- Adams, T. E., J. R. Dunbar, S. L. Berry, W. N. Garrett, T. R. Famula, and Y. B. Lee. 1990. Feedlot performance of beef heifers implanted with Synovex-H: Effect of melengestrol acetate, ovariectomy, or active immunization against GnRH. *J. Anim. Sci.* 68:3079.
- Bloss, R. E., J. I. Northam, L. W. Smith, and R. G. Zimbelman. 1966. Effects of oral melengestrol acetate on the performance of feedlot cattle. *J. Anim. Sci.* 25:1048.
- Brethour, J. R. and J. R. Jaeger. 1989. The single-calf heifer system. *Kansas Agric. Stag. Rep. of Progress* 570.
- Dikeman, M. E. 1984. Cattle production systems to meet future consumer demands. *J. Anim. Sci.* 59:1631.
- Faulkner, D. B., F. K. McKeith, L. L. Berger, D. J. Kesler, and D. F. Parrett. 1989. Effect of testosterone propionate on performance and carcass characteristics of heifers and cows. *J. Anim. Sci.* 67:1907.
- Goodman, J. P., A. L. Slyter, and L. B. Embry. 1982. Effect of intravaginal devices and Synovex-H implants on feedlot performance, cyclic activity, and reproductive tract characteristics of beef heifers. *J. Anim. Sci.* 54:491.
- Jones, S. D. M. 1982. Performance and carcass characteristics of cull dairy cows given testosterone-estradiol implants. *Can. J. Anim. Sci.* 62:295.
- Lauderdale, J. W. 1983. Use of MGA (melengestrol acetate) in animal production. In: E. Meissonnier (Ed.) *Anabolics in Animal Production*. pp 193-232. Office International des Epizooties, Paris.
- O'Brien, C. A., R. E. Bloss, and E. F. Nicks. 1968. Effect of melengestrol acetate on the growth and reproductive physiology of fattening heifers. *J. Anim. Sci.* 27:664.
- NRC. 1984. *Nutrient Requirements of Beef Cattle* (6th Ed.). National Academy Press, Washington, DC.
- Ray, D. E., W. H. Hale, and J. A. Marchello. 1969. Influence of season, sex, and hormonal growth stimulants on feedlot performance of beef cattle. *J. Anim. Sci.* 29:490.

Reiling, B. A., L. L. Berger, D. B. Faulkner, and T. G. Nash. 1993. Effects of melengestrol acetate (MGA) and Synovex-H upon the growth performance and carcass traits of first-calf heifers following early weaning. In: Beef Research Report 1993. pp 74-81. University of Illinois, Urbana.

SAS. 1988. SAS User's Guide: Statistics. SAS Inst., Inc., Cary, NC.

Taylor, St. C. S., A. J. Moore, R. B. Thiessen, and C. M. Bailey. 1985. Efficiency of food utilization in traditional and sex-controlled systems of beef production. Anim. Prod. 40:401.

Waggoner, A. W., M. E. Dikeman, J. R. Brethour, and K. E. Kemp. 1990. Performance, carcass, cartilage, sensory, and collagen traits of longissimus muscles of open versus 30-month-old heifers that produced one calf. J. Anim. Sci. 68:2380.

TABLE 1. EFFECT OF MGA ON PERFORMANCE OF HEIFERS FOLLOWING NORMAL WEANING (205 d) OF THEIR FIRST CALF

Item	No MGA	MGA	SEM	Treatment Effect
No. of Pens	6	6		
On-test wt., kg	329.2	323.0	6.4	.5172
Off-test wt, kg	518.2	529.2	8.4	.3921
56 d ADG, kg/d	1.92	2.15	.08	.0977
Overall ADG, kg/d	1.63	1.78	.04	.0455
Overall DMI, kg/d	12.52	13.41	.34	.1215
Overall gain:feed ratio	.131	.134	.005	.6912

TABLE 2. EFFECT OF MGA CARCASS TRAITS OF HEIFERS FOLLOWING NORMAL WEANING (205 d) OF THEIR FIRST CALF

Item	No MGA	MGA	SEM	Treatment Effect
No. of animals	25	27		
Hot carcass wt, kg	291.7	305.2	5.7	.0966
Longissimus muscle area, cm ²	76.97	82.78	1.67	.0157
Fat thickness, cm	.88	1.10	.07	.0360
Kidney, pelvic and heart fat, %	2.37	2.50	.07	.1789
Yield grade	2.47	2.53	.12	.7081
Marbling	1072	1041	20	.2813
Bone maturity	197	223	13	.1601
Lean maturity	191	210	10	.1824
Percentage choice	48.1	55.2	10.1	.6110

TABLE 3. EFFECT OF SYNOVEX-H ON PERFORMANCE OF HEIFERS FOLLOWING NORMAL WEANING (205 d) OF THEIR FIRST CALF

Item	No Synovex	Synovex	SEM	Treatment Effect
No. of Pens	6	6		
On-test wt, kg	332.7	319.6	6.4	.1946
Off-test wt, kg	526.0	521.4	8.4	.7115
56 d ADG, kg/d	1.91	2.16	.08	.0815
Overall ADG, kg/d	1.67	1.74	.04	.2773
Overall DMI, kg/d	13.02	12.92	.35	.8435
Overall gain:feed ratio	.129	.135	.005	.4126

TABLE 4. EFFECT OF SYNOVEX-H ON CARCASS TRAITS OF HEIFERS FOLLOWING NORMAL WEANING (205 d) OF THEIR FIRST CALF

Item	No Synovex	Synovex	SEM	Treatment Effect
No. of animals	26	26		
Hot carcass wt, kg	297.7	299.2	5.6	.8555
Longissimus muscle area, cm ²	80.08	79.67	1.64	.8630
Fat thickness, cm	1.02	.96	.07	.5614
Kidney, pelvic and heart fat, %	2.43	2.44	.07	.8552
Yield grade	2.51	2.49	.12	.9052
Marbling	1050	1063	20	.6599
Bone maturity	212	209	13	.8905
Lean maturity	203	198	10	.7446
Percentage choice	41.7	61.6	9.9	.1630

THE EFFECTS OF PRENATAL ANDROGENIZATION ON THE PERFORMANCE AND CARCASS COMPOSITION OF LACTATING AND NON-LACTATING SINGLE-CALF HEIFERS.

G. N. Hermesmeier, L. L. Berger, T. R. Carr, B. A. Reiling, and T. G. Nash

SUMMARY

The single-calf heifer (SCH) system can improve beef production efficiency, and prenatal androgenization (PA) has enhanced the performance and carcass composition of heifers in the feedlot. This study evaluated the effects of lactation and PA upon feedlot performance, carcass composition, and organ weights of first-calf heifers. One to two wks post-partum, 14 control (C) and 9 PA lactating (L) heifer-calf pairs and 6 C and 3 PA non-lactating (NL) heifers were weighted and allotted to feedlot pens equipped with pinpoint devices. Heifers were fed an 85% concentrate diet until determined to possess approximately 1.1 cm s.c. fat cover at which time calves were weaned and heifers slaughtered 12 h postweaning. The GLM procedure of SAS was used to analyze the 2 x 2 factorial arrangement of treatments. Because C heifers were fatter than desired, fat thickness was used as a covariate. The L and NL heifers had similar ($P = .45$) ADG's of 1.30 and 1.40 kg/d (SEM = .11), however, L heifers consumed 2.44 kg/d more ($P < .01$) dry matter and G:F was reduced ($P < .01$) from .119 to .091 (SEM = .008). However, the L heifers supported growth of a calf; therefore, overall G:F of the pair was 30% greater ($P < .01$); .155 vs. $.119 \pm .008$) than that of a NL feedlot heifer. The PA heifers gained 4.5% faster, had 3.0% more DMI, and were 2.0% more efficient than the C heifers. The NL heifers had a 9.4% increase ($P < .01$) in marbling score and yield grades were 3.59 and 3.12 (SEM = .16) for NL and L heifers respectively. For L and NL heifers, all internal organ weights as a percent of shrunk weight were similar ($P = .06$), but L heifers had greater ($P < .01$) udder weights as a percent of shrunk weight than did NL heifers. Yield grades were 3.49 and 3.22 (SEM = .15) for C and PA heifers respectively and had similar ($P = .16$) marbling scores. All organ and udder weights as a percent of shrunk weight were similar ($P = .53$) between C and PA heifers. Two carcasses graded C maturity and 67% graded choice.

INTRODUCTION

The SCH system is a new beef cattle production system that can improve production efficiency and profit. Achievement of this efficiency is through combining reproduction with growth for meat production into one animal which should reduce the maintenance costs associated with maintaining the cow. When compared to a cull cow, a calved 2-year-old heifers that achieves a USDA choice grade can be worth 30% more per pound (Brethour and Jaeger, 1989).

Waggoner et al. (1990) found that two year old NL heifers had faster gains than lactating heifers. Non-lactating heifers convert energy intake above maintenance to gain, whereas lactating heifers in addition to maintenance must also meet energy demands for lactation before energy can be utilized for gain. However, feedlot gains of L heifers were similar to yearling NL heifers (Waggoner et al., 1990). Bailey et al. (1991) also found that NL heifers were heavier at the start of the feedlot trail, had 23.5% faster gains, and spent 71 days less in the feedlot than did the contemporary single-calf heifers.

The disadvantages in growth rate, feed efficiency, and carcass cutability of females in comparison to intact and castrated males has been established (Heitzman et al., 1977). However, PA with testosterone propionate (TP) has shown an enhancement in growth performance and feed efficiency so that the heifers perform similar to steers. DeHaan et al. (1988) reported a 19.5% increase in daily gain for heifers when TP was administered between d 80 and 110 of gestation when compared to C heifers. In addition, PA heifers were more efficient in growth and feed conversion than C heifers when fed to a compositional endpoint of 1.2 cm s.c. fat cover (DeHaan et al., 1990).

Reiling et al., (1994) reported that average daily gain was 1.55 and 1.69 kg/d, preweaning, for C and PA heifers respectively. During the 30 day time period between weaning and slaughter, average daily gains (ADG) decreased to 0.54 kg/d for controls and 0.79 kg/d for androgenized heifers. Thus, overall growth performance of heifers was decreased.

MATERIALS AND METHODS

The PA treatment was initiated by placing four 15 cm TP implants subcutaneously posterior the scapula and over the rib cage on the left side of the heifer during gestation. The implants, which were developed from a medical-grade silastic tubing, contained approximately 2.25 g of crystalline TP and administers a secretion rate averaging 37.8 mg TP daily (Kesler, 1987). The TP implants were then removed three weeks pre-partum.

The first-calf heifers used in this study calved at approximately 2 yr of age. Upon calving, routine calving procedures were followed. Dam's and their calves were individually weighed on each of two consecutive days, 10 ± 5 d post-partum, and moved to drylot pens equipped with 4000B or "dummy" pinpointer feeding devices. Non-lactating heifers were also weighed on these days and placed in groups with the heifer-calf pairs. The groups of NL heifers and heifer-calf pairs were then rotated between the two types of pinpointers at intervals of 2 weeks. Heifer's individual intakes were recorded using the pinpointer feeding devices. These intakes were then used to calculate individual intakes from the pen intakes while heifers were in the "dummy" pinpointers. These intakes were estimated by calculating individual heifer's intakes as a percent of total pen intake, while on the

pinpointers. This percentage was then used to calculate the heifer's approximate intake from the "dummy" pinpointers.

Heifers were on feed until they possessed 1.0 cm (.4 in) subcutaneous fat cover as measured by a real-time linear array ultrasound instrument. The heifers were then weighed on each of two consecutive days. The calves remained on the heifers until 12-h before slaughter. The heifers were then processed at either a commercial packing plant or the University of Illinois Meats Laboratory. Organ weights were taken for the heifers processed at the University of Illinois Meats Laboratory. Carcasses were then evaluated for quality and yield grade traits by trained personnel.

RESULTS AND DISCUSSION

Because C heifers were fatter than estimated by ultrasound, fat thickness was used as a covariate. DeHaan et al.(1990) showed a 10.4% improvement and Reiling et al. (1993) showed a 9% improvement in average daily gain of PA feedlot heifers. Though not significant, PA heifers gained 4.5% faster than that of C heifers (Table 3). In addition, PA heifers consumed 3.0% more feed and were 2.0% more efficient than the C heifers. However, the C heifers were on feed for 7 days less than the PA heifers. The L and NL heifers had similar gains of 1.30 and 1.40 kg/d, however, L heifers consumed 2.44 kg/d more ($P < .01$) dry matter (Table 3). The increase in intake therefore caused a decrease ($P < .01$) in gain:feed from .119 to .091. However, when it is considered that the L heifers were supporting the growth of a calf, overall daily gain was increased 78% and overall gain:feed was increased 30%.

There was no significant impact on calf performance due to PA of the heifer. Calf birth weights were 32.1 and 34.5 kg (Table 4) and on-trial weights (2 wk post-partum) were 44.9 and 42.4 kg for C and PA calves respectively. In 1994, Reiling et al. reported calf off-trial weights of 162.3 and 152.1 kg for C and PA calves respectively. The PA calves off-trial weights were 167.2 kg for the C calves and 186.1 kg for the PA calves. This increase in weight gain may be due to the calves remaining on the dam's until 12 hr prior to slaughter.

Carcass traits of heifers are shown in Table 5. Effects of PA and L on carcass composition were assessed using fat and hot carcass weight as covariates. The NL heifers had 13.9% heavier ($P < .05$) hot carcass weights than that of L heifers and fat thickness was similar ($P = .33$). Bone maturity was 189 and 240 ($200 = B^0$ maturity) and marbling scores were 1124 and 1027 ($1000 = \text{Small}^0$) for NL and L heifers. Liver weights were 6.85 and 8.28 kg, kidney weights were 1.01 and 1.22 kg, and full gastric intestinal weights were 94.73 and 116.76 kg (Table 6) for NL and L heifers respectively. However, as a percentage of shrunk weight (Table 7), all internal organ weights were similar ($P = .06$). The L heifers had 101.2% heavier udder weights than that of NL heifers. Due to greater udder

and viscera weights, L heifers had 6.2% lower ($P < .01$) dressing percentage than did NL heifers. Also, 100% of the NL and 50% of the L heifers graded choice, which may be influenced by the small number of NL heifers and the difference in fat thickness for C and PA heifers.

Fat thickness for C and PA heifers were 1.57 and .96 cm ($SEM = .13$) and hot carcass weights were similar ($P = .56$). Bone maturity and marbling scores were similar ($P = .16$) for C and PA heifers. For C and PA heifers all organ weights were similar ($P = .60$). Percent kidney, pelvic, and heart fat was 4.22 and 2.58% ($SEM = .31$) for C and PA heifers respectively. In addition, 83.33% of the C and 66.67% of the PA heifers graded choice.

IMPLICATIONS

For the third consecutive year, we have shown that a first-calf heifer can produce a healthy calf under feedlot conditions and still produce a choice grade carcass. Although results were not as favorable for PA as in past years, PA appeared to provide a slight advantage in daily gains and feed efficiency. Also, when calf production is considered, lactating heifers are more efficient for beef production than traditional feedlot heifers. Therefore, this non-traditional management practice may provide an alternative method for small cattle producers to increase their efficiency of beef production and increase their profits.

REFERENCES

- Bailey, C. M., C. R. Reid, T. P. Ringkob, Y. O. Koh and W. D. Foote. 1991. Nulliparous versus primiparous crossbred females for beef. *J. Anim. Sci.* 69:1403.
- Brethour, J. R. and J. R. Jaeger. 1989. The single-calf heifer system. *Kansas Agric. Sta. Rep. of Progress* 570.
- DeHaan, K. C., L. L. Berger, D. J. Kesler, F. K. McKeith, D. B. Faulkner, G. F. cmarik and R. J. Favero. 1990. Effects of prenatal testosterone treatment and postnatal steroid implantation on growth performace and carcass traits of heifers and steers. *J. Anim. Sci.* 68:2198.
- Heitzman, F. J., K. H. Chan and I. C. hart. 1977. Liveweight gains, blood levels of metabolites, proteins and hormones following implantation of anabolic agents in steers. *Br. Vet. J.* 133:62.
- Kesler, D. J. 1987. Novel approaches and applications of steroid hormone delivery via polydimethylsiloxane. *Proc. Am. Chem. Soc. Div. Poly. Mater. Sci. Eng.* 57:408.
- Reiling, B. A., L. L. Berger, D. B. Faulkner, F. K. McKeith and T. G. Nash. 1994. Effect of prenatal androgenization upon performance and carcass traits of heifers used in a single calving heifer system. In: *Beef Research Report 1994.* pp 48-57. University of Illinois, Urbana.
- Waggoner, A. W., M. E. Dikeman, J. R. Thiessen and K. E. Kemp. 1990. Performance, carcass, crtilage calcium, sensory, and collagen traits of longissimus muscles of open versus 30-month-old heifers that produced one calf. *J. Anim. Sci.* 68:2380.

TABLE 1. COMPOSITION OF DIETS FED^a

Ingredient	Days			
	1-4	5-9	10-14	15 +
Ammoniated corn cobs	45	35	25	15
Corn, whole	40	50	60	70
Corn distillers solubles	5	5	5	5
Pelleted supplement	10	10	10	10

^aPercent of diet (DM basis)

TABLE 2. COMPSITION OF SUPPLEMENT

Ingredient	% as-fed	lbs/ton
Soybean meal	68.70	1374.0
Blood meal	3.20	64.0
Dry molasses	2.58	51.6
Urea	7.52	150.4
Rumensin 60	.20	4.0
Limestone	10.00	200.0
Dicalcium phosphate	2.50	50.0
TM salt + Se	3.50	70.0
Vitamin ADE	.15	3.0
Thiamine premix	.15	3.0
Potassium chloride	1.50	30.0
Total	100.00	2000.0

TABLE 3. EFFECT OF PRENATAL ANDROGENIZATION (PA) UPON PERFORMANCE OF LACTATING AND NON-LACTATING HEIFERS IN A SINGLE CALVING HEIFER SYSTEM

Item	Treatments					P =		
	C*NL	C*L	PA*NL	PA*L	Std. Dev.	Andg.	Lact.	Andg*Lact
No. of animals	6	14	3	9				
Days on test	133	124	136	136	10.4	.12	.33	.33
Heifer on-test wt, kg	515.6 ^{bc}	472.0 ^a	481.2 ^{ab}	548.1 ^c	42.40	.27	.52	<.01
Heifer off-test wt, kg	691.8 ^b	636.4 ^a	677.5 ^{ab}	720.5 ^b	51.31	.13	.78	.03
Heifer DMI, kg/d	11.80	13.79	11.71	14.62	1.236	.50	<.01	.38
Heifer DMI, % of BW	1.97	2.49	2.01	2.31	.181	.39	<.01	.16
Heifer daily gain, kg/d	1.32	1.31	1.48	1.28	.309	.64	.45	.47
Heifer gain:feed	.113 ^b	.096 ^{ab}	.124 ^b	.087 ^a	.0218	.91	<.01	.29
Pair ^d DMI, kg/d		14.47		15.31	1.236	.49		
Pair ^d daily gain, kg/d		2.29		2.33	.390	.56		
Pair ^d gain:feed		.158		.152	.0265	.85		

^{abc}Means with unlike superscripts differ (P < .05).

^dPerformance of heifer and calf combined.

TABLE 4: CALF PERFORMANCE DUE TO PRENATAL ANDROGENIZATION (PA) OF SINGLE-CALF HEIFERS

Item	Control	PA	SEM ^a
Calf birth wt, kg	32.1	34.5	2.2
Calf on-test wt, kg	44.9	42.4	3
Calf off-test wt, kg	167.2	186.1	13.9
Age of calf @ weaning, d	139	150	5
Calf DMI, kg/d	.79	.83	.10
Calf daily gain, kg/d	.98	1.04	.09

^aGreatest standard error of treatment means (SEM) reported.

TABLE 5: EFFECT OF PRENATAL ANDROGENIZATION (PA) AND LACTATION UPON CARCASS COMPOSITION OF HEIFERS IN A SINGLE CALVING HEIFER SYSTEM

Item	Treatment					P=		
	C*NL	C*L	PA*NL	PA*L	Std. Dev.	Andg.	Lact.	Andg*Lact
No. of animals	3	6	3	6				
Hot carcass wt, kg	422.7 ^b	364.2 ^a	402.3 ^{ab}	360.5 ^a	40.13	.56	.03	.68
Dressing %	63.77 ^b	61.03 ^{ab}	64.21 ^b	59.02 ^a	2.032	.60	<.01	.25
Fat thickness, cm	1.65 ^b	1.48 ^b	1.06 ^{ab}	.87 ^a	.357	<.01	.33	.95
Ribeye area, cm ²	82.32	89.98	79.01	88.60	6.239	.60	.04	.76
%KPH fat	4.44 ^b	4.01 ^b	2.58 ^a	2.57 ^a	.684	<.01	.60	.54
Yield grade	3.73 ^b	3.25 ^a	3.46 ^{ab}	2.99 ^a	.349	.30	.04	.96
Heifer age @ slaughter, d	854	835	824	833	28.1	.43	.77	.34
Bone maturity	219	235	160	240	52.8	.44	.14	.30
Lean maturity	165 ^a	212 ^b	215 ^b	202 ^{ab}	19.7	.17	.17	.01
Overall Maturity	188	233	187	224	36.4	.84	.08	.82
Marbling score	1131 ^c	1060 ^b	1116 ^{bc}	993 ^a	38.7	.16	<.01	.20
% Choice	100.00 ^b	66.97 ^{ab}	100.00 ^b	33.33 ^a	43.644	.46	.04	.46

^{abc}Means with unlike superscripts differ (P < .05).

TABLE 6. THE EFFECTS OF PRENATAL ANDROGENIZATION (PA) AND LACTATION UPON ORGAN AND UDDER WEIGHTS OF HEIFERS IN A SINGLE CALVING HEIFER SYSTEM

Item	Treatment					P =		
	C*NL	C*L	PA*NL	PA*L	Std. Dev.	Andg.	Lact.	Andg*Lact
No. of animals	3	6	3	6				
Liver wt, kg	7.03 ^a	8.36 ^b	6.68 ^a	8.21 ^b	.667	.61	<.01	.76
Heart wt, kg	2.09	2.30	2.19	2.45	.353	.63	.29	.87
Kidney wt, kg	1.03 ^a	1.17 ^{ab}	.98 ^a	1.28 ^b	.124	.75	.01	.23
Gastric intestine wt, kg	95.05	112.57	94.41	120.95	16.803	.75	<.05	.60
Udder wt, kg	8.10 ^a	14.73 ^b	6.72 ^a	15.09 ^b	3.015	.81	<.01	.58

^{ab}Means with unlike superscripts differ (P < .05).

TABLE 7: THE EFFECTS OF PRENATAL ANDROGENIZATION (PA) AND LACTATION UPON ORGAN WEIGHTS AS A PERCENT OF SHRUNK WEIGHT OF HEIFERS IN A SINGLE CALVING HEIFER SYSTEM

Item ^a	Treatment					P =		
	C*NL	C*L	PA*NL	PA*L	Std. Dev.	Andg.	Lact.	Andg* Lact
No. of animals	3	6	3	6				
Liver, %	1.19	1.36	1.14	1.29	.126	.53	.06	.89
Heart, %	.35	.37	.37	.39	.058	.62	.61	.97
Kidney, %	.18	.18	.17	.20	.020	.60	.11	.25
Gastric intestine ^b , %	16.05	18.04	16.10	18.91	2.207	.77	.10	.72
Udder, %	1.43 ^c	2.39 ^d	1.24 ^c	2.37 ^d	.447	.75	<.01	.70

^aOrgan weights as a percent of shrunk weight.

^bFull gastric intestine.

^{c,d}Means with unlike superscripts differ (P < .05).

SYNOVEX[®] H AS A PRENATAL ANDROGENIZING AGENT IN BEEF CATTLE: EFFECTS ON THE IMPLANTED PREGNANT HEIFER

S. L. Aldrich, L. L. Berger, D. J. Kesler, D. B. Faulkner, and J. W. Castree

SUMMARY

A study was conducted to evaluate the effectiveness of Synovex[®] H as an agent for prenatal androgenization in beef cattle. Thirty heifers exposed to a fertile bull during a 55 day spring breeding season were randomly assigned to a control group or implanted with three times the normal dose of Synovex[®] H between days 20 and 75 of gestation. Growth performance and testosterone, estradiol, and progesterone concentrations were determined in the heifers that calved. Calving rates were also compared between treatments. Average daily gain was improved 7% by Synovex[®] H treatment. Serum testosterone concentrations were greater ($P < .001$) in treated heifers than in control heifers. There was no effect of Synovex[®] H treatment on serum estradiol concentrations. Serum concentrations of progesterone were decreased ($P < .05$) in the treated heifers. Treatment with Synovex[®] H decreased ($P < .05$) calving rate, 7 of 15 treated heifers (46.7%) calved as compared with 13 of 15 control heifers (86.7%). Birth weight of calves born to treated heifers was 10.3% less ($P < .05$) than that of calves born to control heifers. Calving ease scores were not affected by Synovex[®] H treatment. Results from this study are interpreted to suggest that Synovex[®] H is not an appropriate androgenizing agent due to the adverse effects observed on progesterone concentrations during pregnancy and on calving rate at parturition.

INTRODUCTION

In domestic ruminants, males are heavier at birth and, whether intact or castrate, exhibit faster rates of growth which are characterized by more protein and less fat accretion than that of females. This effect appears to be due, at least in part, to exposure of males but not females to androgens in utero. DeHaan et al. (1988, 1990) reported that modifying the prenatal testosterone environment of heifers improved their postnatal rate and efficiency of growth and composition of gain. Thus, efficiency of beef production could be improved if methods were developed whereby growth rate, feed efficiency, and carcass composition of female cattle could be enhanced to a level similar to that of males.

In our research on prenatal androgenization, silicone implants containing testosterone propionate, which measure .953 cm (o.d.) x 15 cm in length, have been used in cattle

(DeHaan et al., 1988, 1990). Four of these implants, containing approximately 2.25 g testosterone propionate each, are required to elevate plasma concentrations of testosterone in the pregnant cow to the desired 2.0 ng/ml level. These implants are unfeasible for commercial beef production because of their large size, the amount of hormone they require, and the surgical method by which they must be inserted and removed.

Synovex[®] H is a commercially available growth implant for female cattle which contains testosterone propionate and estradiol benzoate. We hypothesized that the testosterone propionate in Synovex[®] H could be used as a prenatal androgenizing agent in cattle. To test this hypothesis, an experiment was conducted to evaluate the effect of Synovex[®] H on growth performance and circulating concentrations of testosterone, estradiol, and progesterone in pregnant beef heifers. Calving rates were also compared between treatments.

MATERIALS AND METHODS

Thirty Charolais-cross yearling heifers (average BW 361 kg) were allotted to treatment in a completely randomized design experiment. Each treated heifer (n = 15) received three Synovex[®] H implants (200 mg testosterone propionate and 20 mg estradiol benzoate/implant; Syntex Animal Health, West Des Moines, IA) between days 20 and 75 of gestation. Control heifers (n = 15) received no implants.

Heifers were exposed to a fertile bull for breeding via natural service over a 55 day spring breeding season. Heifers were rotationally grazed on endophyte-infected fescue-red clover pastures and were given alfalfa-grass hay during the winter. Prior to the calving season, heifers were placed in drylot pens with open front sheds and fed cracked corn (.5% of BW) and were allowed ad libitum access to alfalfa-grass hay and fresh water. Heifers were weighed on day 0, 28, 56, and 84 of Synovex[®] H implantation. At parturition, calving rate, calving ease scores, sex and birth weight of the calves were recorded.

Blood samples (10 ml) were collected from the heifers via coccygeal venipuncture on day 0, 3, 7, 14, 21, 28, 42, 56, 70, and 84 of Synovex[®] H implantation. Concentrations of testosterone, estradiol, and progesterone in serum were determined by the double antibody ELISA procedures of Aldrich et al. (1995).

Performance, hormone concentration, and calf data were analyzed for only the heifers that calved and thus completed the study to ensure that comparisons were made on a homogenous (all pregnant) population of animals. Statistical computation was

performed by the GLM procedure of SAS (1988). Data were analyzed as a completely randomized design (Steel and Torrie, 1980). Effect of treatment (control vs Synovex[®] H) on serum concentrations of testosterone, estradiol, and progesterone were determined by ANOVA for a split plot in time design with repeated measurements (Gil and Hafs, 1971). The statistical model included treatment, day, and treatment x day. Animal within treatment was used as the error term. Mean differences in ADG, serum concentrations of testosterone, estradiol, and progesterone, calf birth weights and calving ease scores were separated by the F-test protected Least Significant Difference method (Carmer and Swanson, 1973). Comparison of calving rates was made by chi-square analysis using the CATMOD procedure of SAS (1988).

RESULTS AND DISCUSSION

Performance, hormone concentration, and calf data are presented for the 7 treated and 13 control heifers that calved and thus completed the study. Synovex[®] H is a steroid implant used to increase rate of gain and improve feed efficiency in female cattle in the feedlot. However, in this study, no statistically significant differences in weight or ADG were observed in heifers treated with three times the normal dose of Synovex[®] H as compared with control heifers (Table 1). Average weight of heifers on the day of Synovex[®] H implantation was 360.8 ± 7.6 kg. Weight of treated and control heifers 84 days post-implantation of Synovex[®] H was similar (434.8 vs 428.7 ± 11.2 kg, respectively). Although not statistically significant, ADG was numerically improved by 7 % in treated vs control heifers ($.88$ vs $.82 \pm .04$ kg/d, respectively).

Synovex[®] H treatment increased ($P < .001$) mean serum concentrations of testosterone in treated heifers as compared with control heifers (Table 2; $.40$ vs $.24 \pm .01$ ng/ml, respectively). Concentrations of testosterone were similar between treatments on day 0, elevated in treated heifers on day 3, 7, 14, 21, 28, 42, and 56, and similar on day 70 and 84 of Synovex[®] H treatment (Figure 1). Results from this study indicate that the pay-out period of the Synovex[®] H implant was approximately 60 days for testosterone (Figure 1). The dose of testosterone propionate used in this study was 600 mg, which was much less than the 4.5 g and 9 g used in previous studies (DeHaan et al., 1988, 1990; respectively). Consequently, serum concentrations of testosterone in the treated heifers in this study were considerably less, at $.40$ ng/ml, than the 2 ng/ml concentration previously reported (DeHaan et al., 1987).

In addition to testosterone propionate, Synovex[®] H contains estradiol benzoate. Although the dose of estradiol benzoate received by the treated heifers was 60 mg, mean serum concentrations of estradiol were similar in treated and control heifers (Table 2; 216.0 vs 217.6 ± 8.4 pg/ml, respectively); concentrations were similar at all

times throughout the 84 day blood collection period (Figure 1). Thus, at initial evaluation of hormone concentrations achieved by this dose of Synovex[®] H, the presence of estradiol appeared to be irrelevant.

Mean serum concentrations of progesterone in treated heifers were lower ($P < .05$) as compared with control heifers (Table 2; 1.87 vs $2.78 \pm .10$ ng/ml, respectively). Concentrations of progesterone were similar between treatment groups on day 0; however, by day 3 and throughout the remainder of the 84 day blood collection period serum progesterone was lower ($P \leq .05$) in the treated heifers as compared with control heifers (Figure 1).

Synovex[®] H contains both testosterone and estradiol, and of the 15 treated heifers, only 7 (46.7%) calved as compared with 13 of 15 control heifers (86.7%). Although it cannot be directly stated that treatment with Synovex[®] H during early gestation caused abortion in the treated heifers that did not calve, based on progesterone concentrations in the treated heifers that did calve, it appeared that Synovex[®] H had a suppressive effect on progesterone and thus may have contributed to calf mortality in these heifers. Specifically, calving rate differed ($P < .05$) between treatments with 7 of 15 treated heifers (46.7%) calving as compared with 13 of 15 control heifers (86.7%; Table 3). These data suggest that this combination of estradiol, with testosterone, in early gestation caused mortality, possibly by modifying luteal function or interfering with maternal recognition of pregnancy.

In addition, the heifers were grazing endophyte-infected fescue pastures. Reduced reproductive efficiency, specifically reduced calving rates, in cattle grazing endophyte-infected fescue has been reported. Thus, the endophyte-infected fescue pasture may have contributed to the increased calf mortality in the treated heifers as compared with the control heifers because the treated heifers were already facing a compromised pregnancy as evaluated by their decreased serum progesterone concentrations.

Calves born to treated heifers weighed 10.3% less ($P < .05$) than calves born to control heifers (Table 3; 33.3 vs 37.1 ± 1.1 kg, respectively). However, calving ease scores were similar between treated and control heifers (Table 3; 2.1 vs $1.7 \pm .4$, respectively).

CONCLUSIONS

Treatment of pregnant beef heifers with Synovex[®] H for the purpose of prenatally androgenizing the female offspring increased serum concentrations of testosterone in the treated heifers, but had an adverse effect on calving rates, possibly through

decreased progesterone concentrations and is therefore not recommended for this purpose until further research has been conducted.

LITERATURE CITED

- Aldrich, S. L., L. L. Berger, D. J. Kesler, D. B. Faulkner, and J. W. Castree. 1995. Synovex H as a prenatal androgenizing agent in beef cattle: Effects on the implanted pregnant heifer. *J. Anim. Sci.* (Submitted).
- Carmer, S. G., and M. R. Swanson. 1973. An evaluation of ten pair-wise multiple comparison procedures by Monte Carlo methods. *J. Am. Stat. Assoc.* 18:66.
- DeHaan, K. C., L. L. Berger, D. J. Kesler, F. K. McKeith, D. B. Faulkner, and G. F. Cmarik. 1988. Effect of prenatal androgenization on growth performance and carcass characteristics of steers and heifers. *J. Anim. Sci.* 66:1864.
- DeHaan, K. C., L. L. Berger, D. J. Kesler, F. K. McKeith, D. B. Faulkner, G. F. Cmarik, and R. J. Favero. 1990. Effects of prenatal testosterone treatment and postnatal steroid implantation on growth performance and carcass traits of heifers and steers. *J. Anim. Sci.* 68:2198.
- DeHaan, K. C., L. L. Berger, D. J. Kesler, F. K. McKeith, D. L. Thomas, and T. G. Nash. 1987. Effect of prenatal androgenization on lamb performance, carcass composition and reproductive function. *J. Anim. Sci.* 65:1465.
- Gill, J. L., and H. D. Hafs. 1971. Analysis of repeated measurements of animals. *J. Anim. Sci.* 33:331.
- SAS. 1988. SAS/STAT® User's Guide (Release 6.03). SAS Inst. Inc., Cary, NC.
- Steel, R. G. D., and J. H. Torrie. 1980. Principles and Procedures of Statistics: A Biometrical Approach (2nd Ed.). McGraw-Hill Book Co., New York, NY.

TABLE 1. EFFECT OF SYNOVEX® H ON WEIGHT AND AVERAGE DAILY GAIN DURING PREGNANCY IN BEEF HEIFERS^a

Item	Control	Treated ^b	SEM	P =
No. of heifers	13	7		
On-test wt., kg	359.5	360.7	10.32	.9275
Off-test wt., kg	428.7	434.8	11.16	.6655
ADG, kg/d	.824	.882	.0365	.2130

^aWeight and average daily gain of the 13 of 15 control and 7 of 15 treated heifers that calved and thus completed the study.

^bEach treated heifer received 3 Synovex® H implants (200 mg testosterone propionate and 20 mg estradiol benzoate/implant) between d 20 and 75 of gestation.

TABLE 2. EFFECT OF SYNOVEX® H ON MEAN CONCENTRATIONS OF SERUM TESTOSTERONE, ESTRADIOL, AND PROGESTERONE DURING PREGNANCY IN BEEF HEIFERS^a

Item	Control	Treated ^b	SEM	P =
No. of heifers	13	7		
Testosterone, ng/ml	.245	.401	.0095	.0001
Estradiol, pg/ml	217.6	216.0	8.43	.9331
Progesterone, ng/ml	2.78	1.87	.104	.0285

^aMean serum concentrations of hormones in the 13 of 15 control and 7 of 15 treated heifers that calved and thus completed the study.

^bEach treated heifer received 3 Synovex® H implants (200 mg testosterone propionate and 20 mg estradiol benzoate/implant) between d 20 and 75 of gestation.

TABLE 3. EFFECT OF SYNOVEX® H DURING PREGNANCY ON PARTURITION IN BEEF HEIFERS

	Control	Treated ^a	SEM	P =
Calving rate, %	13/15 (86.7)	7/15 (46.7)	.4596	.0291
Sex of calf, #				
Male	8	4		
Female	5	3		
Calf birth wt., kg	37.1	33.3	1.13	.0147
Calving ease score ^b	1.71	2.11	.451	.4896

^aEach treated heifer received 3 Synovex® H implants (200 mg testosterone propionate and 20 mg estradiol benzoate/implant) between d 20 and 75 of gestation.

^b1 = no difficulty, 2 = minor difficulty, 3 = major difficulty, 4 = caesarean section, 5 = abnormal presentation.

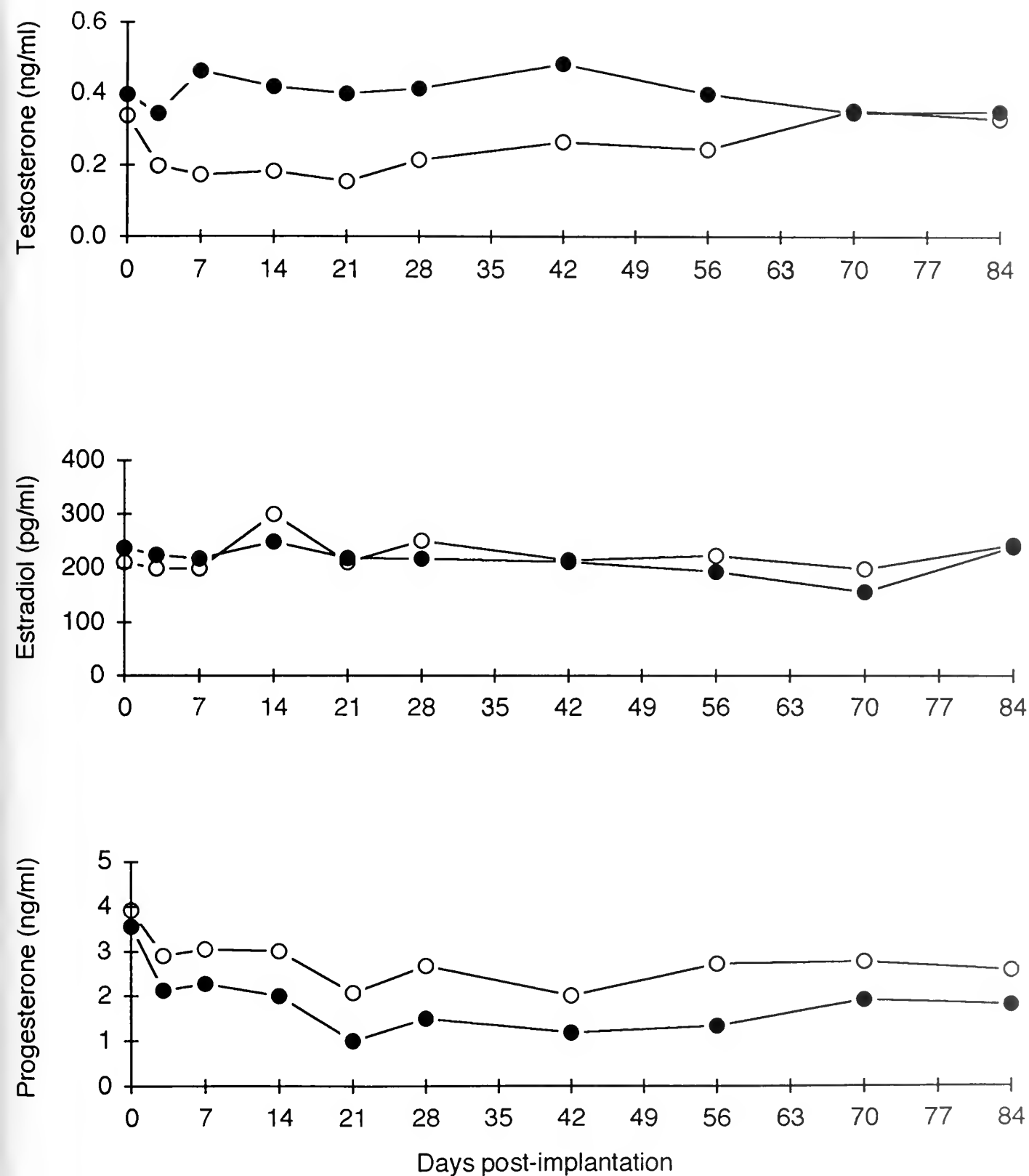


Figure 1. Serum testosterone, estradiol, and progesterone in 7 treated (—●—) and 13 control (—○—) pregnant beef heifers from d 0 to 84 post-implantation with 3 Synovex[®] H implants/heifer (200 mg testosterone propionate and 20 mg estradiol benzoate/implant).

PARTURITION, POSTPARTUM OVARIAN FUNCTION, AND LACTATION HORMONES IN PRENATALLY ANDROGENIZED PRIMIPAROUS BEEF HEIFERS

S. L. Aldrich, L. L. Berger, B. A. Reiling, D. J. Kesler, and T. G. Nash

SUMMARY

Forty-three heifers in a single calving heifer system trial were studied to determine the effects of prenatal androgenization on parturition, postpartum ovarian function, and lactation hormones. Seven androgenized and 7 control heifers were used for blood collection at calving and during lactation; and all heifers were used for blood collection to determine postpartum ovarian function. Serum concentrations of progesterone, estradiol, testosterone, prostaglandin $F_{2\alpha}$, and prolactin from 10 days prior until 3 days after parturition were similar for androgenized and control heifers. Likewise, calf birth weights and calving ease scores were similar between the 2 groups of heifers. Postpartum ovarian function was similar, with 6 of 22 androgenized (27.3%) and 3 of 21 (14.3%) control heifers cycling by 70 days postpartum, based on weekly progesterone concentrations. Serum concentrations of insulin, triiodothyronine, and prolactin at 5, 10, and 15 weeks of lactation were similar for androgenized and control heifers; thyroxine concentrations were similar at 5 and 10 weeks, but greater ($P < .001$) at 15 weeks of lactation in androgenized than in control heifers. In addition, while mean serum concentrations of insulin, triiodothyronine, and thyroxine were similar, prolactin was greater ($P < .05$) in control than in androgenized heifers. We conclude that androgenized heifers are similar to control heifers with respect to parturition, postpartum ovarian function, and lactation hormones; thus management requirements of androgenized primiparous beef heifers appear to be similar to that of control primiparous beef heifers.

INTRODUCTION

Prenatal exposure to androgens improves postnatal rate and efficiency of growth and composition of gain in beef heifers. These prenatally androgenized heifers can be used in a calving heifer system to improve efficiency of beef production. Specifically, the heifers can efficiently produce both weight gain and milk simultaneously under feedlot conditions; however, the reproductive management practices required to maintain prenatally androgenized heifers has not been reported. Observations during our first year of study on prenatally androgenized heifers in a calving heifer system indicated potential calving difficulties as well as alterations in postpartum ovarian function and milk production. This led us to hypothesize that prenatal exposure to androgens may negatively impact reproductive performance and alter milk production of primiparous beef heifers. Therefore, the objectives of this study were to determine the effects of prenatal androgenization on parturition, postpartum ovarian function, and lactation hormones in primiparous beef heifers in a calving heifer system.

MATERIALS AND METHODS

Forty-three primiparous Angus x Simmental heifers, 22 prenatally androgenized and 21 control, were allotted to treatment in a completely randomized design experiment. Fourteen heifers, 7 prenatally androgenized and 7 control, were used for blood collection at calving and during lactation; and all heifers were used for blood collection to determine postpartum ovarian function. Calf sex and birth weight, and calving ease scores were recorded at parturition. Cow-calf pairs were placed in the feedlot for a single calving heifer system trial.

Blood samples were collected daily via jugular venipuncture beginning 10 days prior to and continuing until 3 days after calving to determine the hormone profile at parturition. Blood samples were collected once weekly via jugular venipuncture beginning 25 days postpartum and continuing until 70 days postpartum for determination of postpartum ovarian function. Ovarian activity was defined by the occurrence at 7 day intervals of progesterone concentrations of 1.5 ng/ml or greater. Blood samples were collected via jugular venipuncture at 5, 10, and 15 weeks of lactation to determine hormone concentrations during lactation.

Serum concentrations of insulin, thyroxine (T₄), and triiodothyronine (T₃) were determined by solid phase RIA procedures (Coat-A-Count[®] Insulin, Coat-A-Count[®] Total T₄, and Coat-A-Count[®] Total T₃, respectively; Diagnostic Products Corp., Los Angeles, CA). Serum concentrations of progesterone, estradiol, and testosterone were determined by the ELISA procedures of Aldrich et al. (1995). Serum concentrations of prostaglandin F_{2α}, as measured by its stable metabolite, 13,14-dihydro-15-keto PGF_{2α} (PGFM), were determined by the RIA procedure of Homanics and Silvia (1988) as modified by Zollers et al. (1989). Prolactin concentrations in serum were determined by the RIA procedure of Rozell and Keisler (1990).

Statistical computations were performed by the GLM procedure of SAS (1988). Data were analyzed as a completely randomized design (Steel and Torrie, 1980). Effect of treatment (control vs prenatal androgenization) on serum concentrations of progesterone, estradiol, testosterone, prolactin, and PGFM at parturition was determined by ANOVA for a split plot in time design with repeated measurements (Gil and Hafs, 1971). The statistical model included treatment, day, and treatment x day. Animal within treatment was used as the error term. Effect of treatment (control vs prenatal androgenization) on serum concentrations of insulin, T₄, T₃, and prolactin during lactation was determined by ANOVA for a split plot in time design with repeated measurements (Gil and Hafs, 1971). The statistical model included treatment, week, and treatment x week. Animal within treatment was used as the error term. Mean differences in calf birth weight, calving ease score, and serum concentrations of insulin, T₄, T₃, and prolactin were separated by the F-test protected Least Significant Difference method (Carmer and Swanson, 1973). Comparison of ovarian activity by 70 days postpartum was made by chi-square analysis using the CATMOD procedure of SAS (1988).

RESULTS AND DISCUSSION

Serum concentrations of progesterone, estradiol, testosterone, PGFM, and prolactin were similar for androgenized and control heifers during the 10 days prior to parturition and 3 days after parturition (Figure 1 and 2). Although there was a trend ($P = .1496$) for lower serum progesterone concentrations during the 10 days prior to parturition in the control heifers as compared with the androgenized heifers, by day -1 through day 3 postpartum, progesterone concentrations were similar between the 2 groups of heifers. The characteristic rise in estradiol at the onset of parturition and sharp decline following parturition was observed in both groups of heifers. Serum testosterone concentrations were similar between groups and declined slightly during the 3 days following parturition. Serum concentrations of PGFM were virtually undetectable during the 10 days prior to parturition, however rose sharply at parturition in both groups of heifers. Prolactin concentrations in serum were low prior to parturition and rose dramatically at parturition before again declining. In addition, calf birth weights and calving ease scores were similar for androgenized and control heifers (Table 1). Average birth weight for all calves was $34.7 \pm .9$ kg and average calving ease score was $1.34 \pm .14$ on a scale of 1 = no difficulty to 5 = abnormal presentation.

Postpartum ovarian function was similar for androgenized and control primiparous beef heifers. By 70 days postpartum, 6 of 22 androgenized heifers (27.3%) and 3 of 21 control heifers (14.3%) were cyclic, based on weekly serum progesterone concentrations. The remaining PA and C heifers had undetectable levels of progesterone to 70 days postpartum, and were therefore considered to still be postpartum anestrus 70 days after calving.

Serum concentrations of insulin, T₄, T₃, and prolactin during lactation are presented in Table 2. Mean insulin, T₄, and T₃ concentrations were similar for all heifers; while prolactin was greater ($P < .05$) in control heifers than in androgenized heifers. Specifically, although the standard error was large, mean prolactin concentrations were 46.6% greater in control than in androgenized heifers (88.6 vs 47.3 ± 9.62 ng/ml). The reason for this difference is presently unclear. During weeks 5, 10, and 15 of lactation, serum concentrations of insulin, T₃, and prolactin were similar for the two groups of heifers; however, at 15 weeks of lactation, T₄ was greater ($P < .001$) in the androgenized heifers than in the control heifers (85.0 vs 71.8 ± 2.23 ng/ml).

CONCLUSIONS

Prenatally androgenized heifers are similar to control heifers with respect to parturition, postpartum ovarian function, and lactation. Therefore, management requirements of androgenized primiparous beef heifers appear to be similar to that of control primiparous beef heifers, and these heifers can be successfully used in a calving heifer system program.

LITERATURE CITED

Aldrich, S. L., L. L. Berger, D. J. Kesler, D. B. Faulkner, and J. Castree. 1995. Synovex® H as a prenatal androgenizing agent in beef cattle: Effects on the implanted pregnant heifer. J. Anim. Sci. (Submitted).

Carmer, S. G., and M. R. Swanson. 1973. An evaluation of ten pair-wise multiple comparison procedures by Monte Carlo methods. J. Am. Stat. Assoc. 18:66.

Gill, J. L., and H. D. Hafs. 1971. Analysis of repeated measurements of animals. J. Anim. Sci. 33:331.

Homanics, G. E., and W. J. Silvia. 1988. Effects of progesterone and estradiol-17β on uterine secretion of prostaglandin F2α in response to oxytocin in ovariectomized ewes. Biol. Reprod. 38:804.

Rozell, T. G., and D. H. Keisler. 1990. Effects of oestradiol on LH, FSH and prolactin in ovariectomized ewes. J. Reprod. Fertil. 88:645.

SAS. 1988. SAS/STAT® User's Guide (Release 6.03). SAS Inst. Inc., Cary, NC.

Steel, R. G. D., and J. H. Torrie. 1980. Principles and Procedures of Statistics: A Biometrical Approach (2nd Ed.). McGraw-Hill Book Co., New York, NY.

Zollers, Jr., W. G., H. A. Garverick, and M. F. Smith. 1989. Oxytocin-induced release of prostaglandin F2α in postpartum beef cows: Comparison of short versus normal luteal phases. Biol. Reprod. 41:262.

TABLE 1. CALF BIRTH WEIGHTS AND CALVING EASE SCORES FOR CONTROL AND ANDROGENIZED PRIMIPAROUS BEEF HEIFERS

	Control	Androgenized	SEM	P =
No. of heifers calving	21	22		
Calf birth weight, kg	35.5	34.3	.95	.3742
Calving ease score ^a	1.34	1.35	.144	.9802

^a1 = no difficulty, 2 = minor difficulty, 3 = major difficulty, 4 = caesarean section, 5 = abnormal presentation.

TABLE 2. SERUM CONCENTRATIONS OF HORMONES DURING LACTATION IN CONTROL AND ANDROGENIZED PRIMIPAROUS BEEF HEIFERS

	Control	Androgenized	SEM	P =
No. of heifers	7	6		
Insulin, ng/ml				
Weeks Postpartum			0.197	0.6960
5	0.57	1.02		
10	1.46	1.71		
15	1.25	1.38		
Mean concentration	1.09	1.37	0.114	0.2927
T ₄ , ng/ml				
Weeks Postpartum			2.23	0.0020
5	68.6	70.0		
10	72.3	70.2		
15	71.8	85.0		
Mean concentration	70.9	75.1	1.29	0.4103
T ₃ , ng/ml				
Weeks Postpartum			0.058	0.1285
5	1.44	1.54		
10	1.44	1.49		
15	1.48	1.75		
Mean concentration	1.45	1.59	0.033	0.1751
Prolactin, ng/ml				
Weeks Postpartum			16.67	0.7753
5	92.9	41.9		
10	89.6	45.2		
15	83.3	54.8		
Mean concentration	88.6	47.3	9.62	0.0291

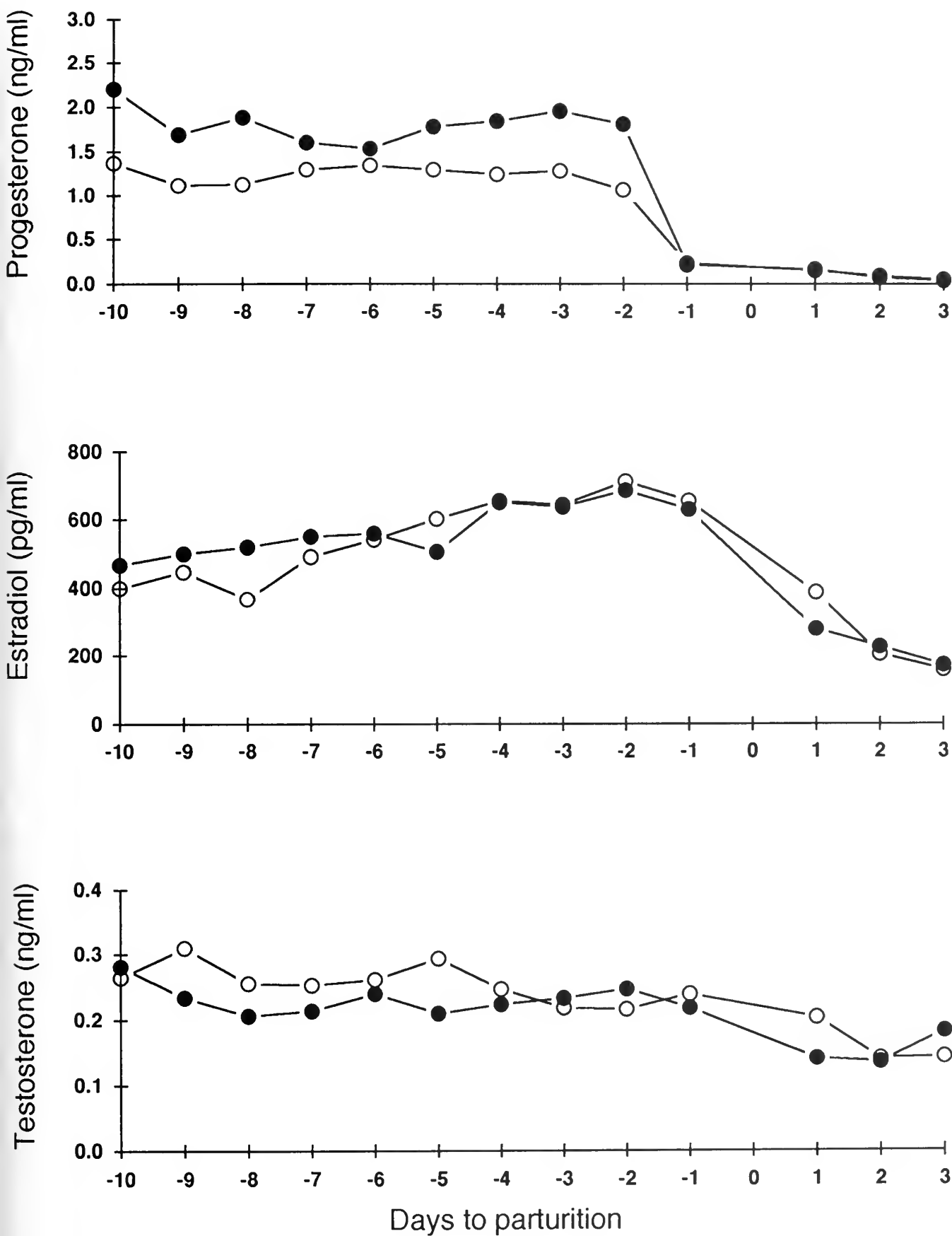


Figure 1. Serum concentrations of progesterone, estradiol, and testosterone at the time of parturition in 7 androgenized (—●—) and 7 control (—○—) primiparous beef heifers.

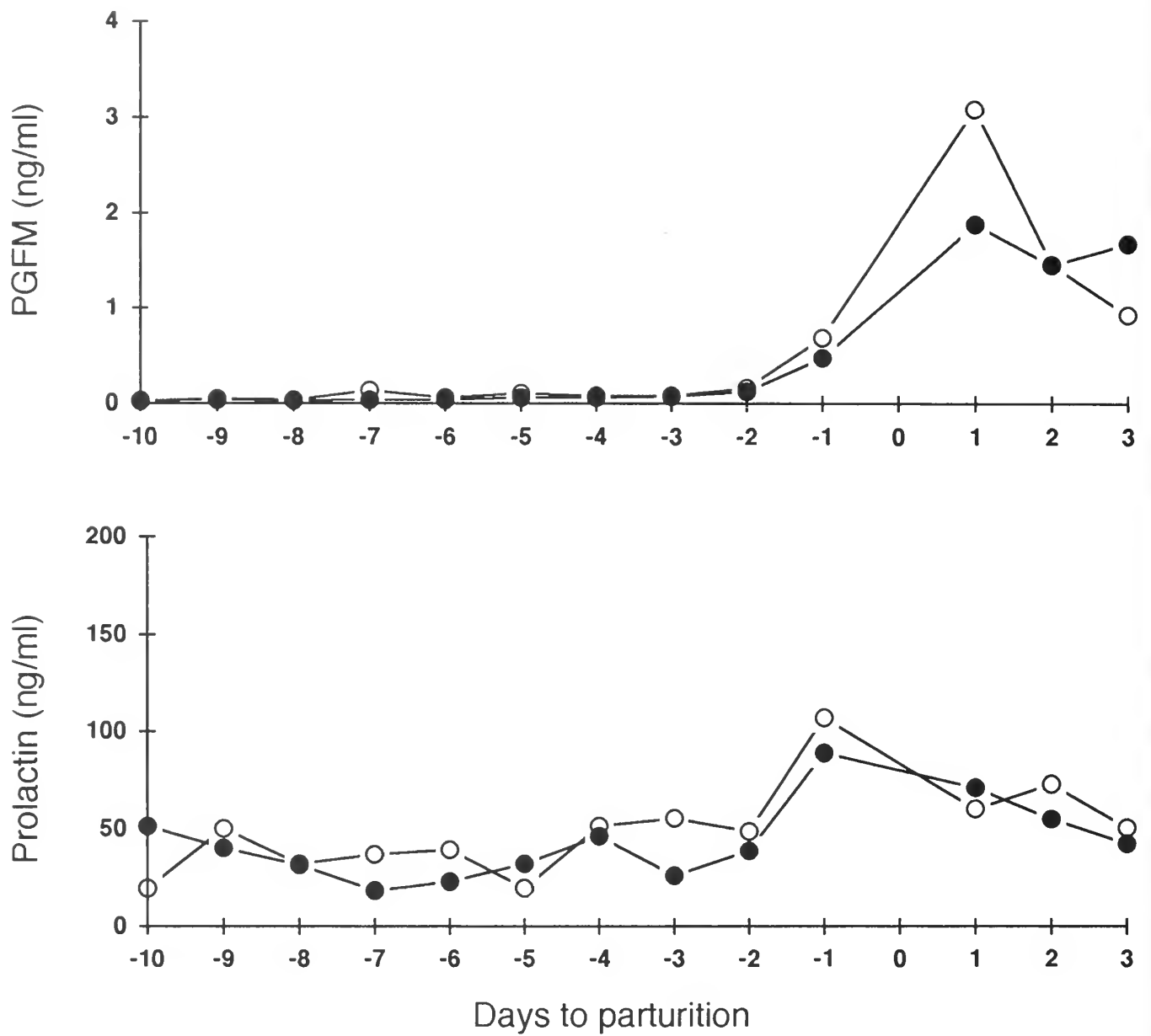


Figure 2. Serum concentrations of PGFM and prolactin at the time of parturition in 7 androgenized (—●—) and 7 control (—○—) primiparous beef heifers.

CONTROLLED DELIVERY OF TESTOSTERONE PROPIONATE SUPPRESSES FERTILITY IN TREATED FEMALES AND INDUCES PRENATAL ANDROGENIZATION IN FEMALE OFFSPRING WITHOUT PHENOTYPIC MASCULINIZATION

D.J. Kesler, R.J. Favero, J.C. Esarey, and L.L. Berger

SUMMARY

Four experiments were conducted on the controlled delivery of testosterone propionate in cattle and sheep. Blood testosterone concentrations were more consistent across time when silicone implants were used for delivery than when compressed pellets were used for delivery. Heifers with high testosterone concentrations were infertile. Female offspring born to heifers exposed to a consistent delivery of testosterone propionate, beginning before and continuing throughout gestation, had normal female phenotype. Prenatally androgenized females were at least as fertile as untreated heifers. Combined, the four experiments demonstrate that 1) testosterone suppresses fertility of treated females, and 2) phenotypic masculinization and sterility of female offspring can be avoided when androgens are delivered prenatally by controlled release implants regardless of stage of gestation when treated.

INTRODUCTION

Researchers are continually seeking methods to enhance meat animal growth and feed efficiency. In particular, enhancement of growth and feed efficiency of female cattle and sheep are desired since males, whether intact or castrate, exhibit faster rates of growth which are characterized by more protein and less fat accretion than that of females. One method that has been developed is prenatal treatment with androgens: prenatal androgenization.

Prenatal androgenization involves exposing in utero offspring to androgens during the "critical period" of sexual differentiation. The brain controls a variety of functions, including behavior, body weight, and hypothalamic/pituitary hormone secretions, that differ in males and females (9, 10, 17). During the "critical period" the brain sexually differentiates and male phenotype develops as a result of male androgens produced by the developing testes. Even genotypic males differentiate into phenotypic females if male androgens are not present or are ineffective. Exposing in utero female offspring to male androgens will induce varying degrees of differentiation from complete phenotypic masculinization (including the presence of a penis and an empty scrotal sac; 1, 19) to no phenotypic masculinization (3, 4, 6, 7). Growth rate and feed efficiency are enhanced by about 15 % (3, 4, 6, 7).

Two basic delivery procedures have been used to accomplish prenatal androgenization: injection or implantation of androgens. In general, offspring resulting when injections were administered early in gestation developed male phenotypic characteristics and had growth characteristics similar to males (16, 19). In one study (11), however, male phenotypic characteristics were not obtained but neither were improved growth characteristics. In fact, the average daily gain of the androgenized heifers from birth to weaning was less than for the control heifers (11). Implants were used to deliver the androgens in other studies. In all of those studies (3, 4, 6, 7), except one (1), the female offspring had female phenotype and enhanced growth characteristics. The exception, Clarke et al. (1), used compressed pellets to deliver testosterone as compared to the other studies that used silicone implants. Therefore, in all reported studies outside our laboratory (3, 4, 6, 7), enhanced growth characteristics were obtained in female offspring when they displayed male phenotype.

There are several factors that are potentially critical to prenatal androgenization: 1) dosage of androgen, 2) androgen used, 3) timing of administration (including when initiated and duration), and 4) delivery profile of the androgen administered. The following four experiments (in support with data in the literature) were conducted to demonstrate that a controlled delivery of androgen prenatally induces improved growth characteristics of female offspring without changes in phenotype. In addition, the effect of testosterone on the fertility of treated adult females was evaluated.

MATERIALS AND METHODS

Experiment 1. Six non-pregnant mature (non-growing) ewes were used for this study. Three testosterone compressed pellets were manufactured with a hand press with testosterone (mean = 1.001 g/pellet; C.V. = 1.03 %). Three capsule type silicone implants (10 cm in length) were manufactured with testosterone propionate (approximately 1.5 g of testosterone propionate per implant; C.V. = 0.75 %). Three ewes were implanted with one compressed pellet each in the neck (1) and three ewes were implanted with one silicone implant each in the axilla (3, 7). All implants were left in situ for 50 days. After removal, the implants were dried under heat (40°) for 72 hours and weighed to determine hormone loss in vivo.

Immediately before implantation (time 0), 1, 2, and 4 hours, and 1, 3, 7, 10, 14, 17, 21, and 50 days after implantation blood samples were collected for testosterone determination via a validated enzyme immunoassay (13).

The hypothesis of experiment 1 was that blood testosterone concentrations in animals administered androgens from silicone implants would be more consistent than in animals administered androgens from compressed pellets. Therefore, this could be a factor causing the differences observed in animals prenatally androgenized with these two procedures.

Experiment 2. Forty-eight (growing) yearling crossbred beef heifers were randomly assigned to four groups: 1) untreated controls, 2) heifers implanted with Synovex® H [compressed pellets containing testosterone propionate; one on day 0 and another on day 84], 3) heifers implanted with testosterone propionate silicone implants [one 15 cm implant on day 0 and another on day 84], and 4) heifers implanted with two 15 cm implants on day 0. Synovex® H implants were placed subcutaneously on the convex surface of the ear and testosterone propionate/silicone implants were implanted subcutaneously behind the shoulder and over the dorsal aspect of the rib cage. Blood samples were collected via jugular venipuncture prior to treatment (day 0) and on days 28, 56, 84, 112, 140, 156 (day of implant removal), and on day 158. Concentrations of progesterone and testosterone were determined with validated enzyme immunoassays (13).

This study was conducted to determine the blood testosterone concentrations of heifers administered testosterone propionate via silicone implants or by compressed pellets and to determine if our hypothesis, that high concentrations of testosterone administration would suppress female fertility, was correct.

Experiment 3. Twenty-five crossbred beef heifers, approximately 15 months of age, were randomly assigned to treated (n = 13) or control (n = 12) groups. The treated heifers were subcutaneously implanted with four capsule type testosterone propionate implants (each 15 cm in length). The implants were placed behind the shoulder and over the dorsal aspect of the rib cage. Three days after the treated heifers were implanted, all females were exposed to a single fertile bull for 75 days. On days 36 and 102 after the beginning of the breeding season, serum samples were collected for the determination of testosterone concentrations using validated enzyme immunoassay (13). Blood samples collected on day 105 were also assayed for progesterone concentrations using a validated enzyme immunoassay (13). Approximately 3 weeks before the onset of the calving season the testosterone propionate implants were removed.

At calving the number, genotype, and phenotype of the resulting offspring were recorded. All female offspring were maintained. At approximately 13 months of age the female offspring (both treated and untreated) were administered Syncro-Mate B® to determine cyclicity (from blood progesterone concentrations [≥ 1.5 ng/ml] on day 13 after implant removal). At approximately 15 months of age the heifers were again administered Syncro-Mate B® and were artificially inseminated subsequent to synchronization. Females were observed for estrus over the next 30 days and were bred by artificial insemination subsequent to estrus. On day 30, females were exposed to a fertile bull for the remainder of the 65 day breeding season. Pregnancy status was determined per rectum 45 days after the end of the breeding season.

The hypothesis of experiment 3 was that testosterone propionate exposure in a controlled and consistent manner would induce prenatal androgenization without

complete masculinization regardless of how early in prenatal development the androgens were administered.

Experiment 4. Crossbred beef females (n = 235) were randomly assigned to treated or control groups 30 days after the end of a 60 day breeding season. Treated females were subcutaneously implanted with four capsule type testosterone propionate implants (each 15 cm in length). Implants were removed approximately 3 weeks before the onset of the calving season.

The resulting offspring (trial 1) of the testosterone propionate treated cows (n = 50) and of the untreated cows (n = 66) were weaned from their dams at approximately 7 months of age and were retained as replacement heifers. At approximately 12 to 14 months of the age the heifers were synchronized with Syncro-Mate B® (14). Heifers were artificially inseminated approximately 47 hours after norgestomet implant removal. Heifers that had subsequent estrus were bred either artificially or naturally for a 70 day breeding season. Pregnancy was determined per rectum 63 and 153 days after the timed breeding.

A second group (trial 2) of 71 cross-bred heifers (41 controls and 30 prenatally androgenized) were evaluated for fertility. At approximately 12 to 14 months of the age the heifers were synchronized with Syncro-Mate B® (14). Heifers were artificially inseminated approximately 47 hours after norgestomet implant removal. Forty-five days after the timed insemination pregnancy was determined per rectum. No additional data were collected from these heifers.

The hypothesis of experiment 4 was that offspring born to prenatal androgenization (with testosterone administered in a controlled and consistent manner) would have normal postnatal reproductive function.

Implants and Implantation. The silicone implants were made from medical grade silicone tubing and testosterone propionate as previously described (12, 15). The medical grade silicone tubing had an internal diameter of .635 cm and an external diameter of .953 cm. After manufacturing the implants, they were rinsed with absolute ethanol and dried. They were then coated with a lyophilized antibiotic.

The implants were surgically implanted without anesthesia with a scalpel, a hemostat to separate the skin from the subcutaneous tissue, and a suture to close the wound. The implantation area was cleaned and disinfected both immediately before and after implanting. Implants were surgically removed with a scalpel and a hemostat after cleaning and disinfecting the area.

Testosterone propionate was used in the silicone implants because of previous data (2) that demonstrated that about four times more testosterone propionate than testosterone diffused through silicone in a given period of time. Testosterone

propionate is rapidly converted to native testosterone shortly after diffusion from the implant (21).

Blood Collection. Blood was collected using 10 cc syringes and 18 gauge needles 3.81 cm long. After collection, the blood was stored in glass culture tubes until centrifugation which was done within 6 hours after collection (23). Serum was harvested after centrifugation and stored in plastic vials at -20°C until it was assayed for progesterone and/or testosterone concentrations.

Syncro-Mate B®. Syncro-Mate B® consists of implantation of a 6 mg norgestomet implant and injection of 5 mg of estradiol valerate and 3 mg of norgestomet on the same day. The implant is placed subcutaneously on the convex surface of one ear and left in situ for 9 days. Females are bred at a fixed time, 47 to 52 hours, after implant removal.

Synovex® H. Synovex® H implants are compressed pellets that contain 200 mg of testosterone propionate and 20 mg of estradiol benzoate. They are used as anabolic implants for feedlot heifers.

Data Analysis. Qualitative data were analyzed by Chi-square analysis and quantitative data were analyzed by analysis of variance (22).

RESULTS AND DISCUSSION

Experiment 1. The testosterone pellets released 357.8 mg of testosterone. The testosterone propionate/silicone implants secreted 444.2 mg of testosterone propionate. This is equivalent to 372.9 mg of testosterone which is within 4.0 % of the quantity of testosterone release from the testosterone pellets.

Testosterone concentrations across time are illustrated in figure 1. There was a burst release detected for the ewes implanted with the pellets which was not detected for the ewes implanted with the testosterone propionate/silicone implants. Blood testosterone concentrations for both implantation methods were within the same general range although blood testosterone concentrations for the ewes implanted with testosterone propionate/silicone implants were higher than for the ewes implanted with testosterone pellets during most of the study period (mean testosterone concentrations on days 1 to 50 of 3.1 ng/ml and 4.7 ng/ml for pellet and silicone groups, respectively). Although testosterone concentrations increased more rapidly for ewes implanted with a testosterone pellet, the increase for the ewes implanted with silicone implants was also relatively rapid (concentrations were one-half of the day one sample 2 hours after implantation [hour +2 mean = 1.8 ng/ml]). Blood testosterone concentrations were less consistent for the testosterone pellet implanted ewes than for the silicone implanted ewes (see figure 1).

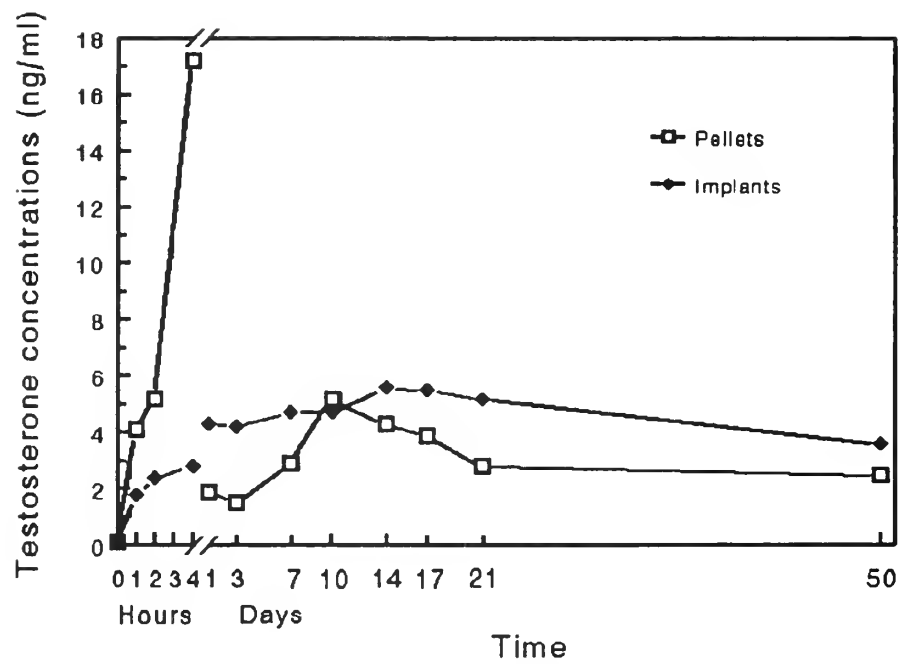


Figure 1. Blood testosterone concentrations in ewes administered testosterone compressed pellets or testosterone propionate silicone implants.

Although no controlled behavior tests were conducted, the three ewes administered the testosterone pellets became very aggressive during the study period. The three ewes administered the testosterone propionate/silicone implants did not display this aggressive/fighting behavior. We have previously demonstrated that an injection (and the resulting spike in testosterone concentrations) superimposed on the constant delivery of testosterone induced male sexual behavior (15, 18, 20). The spike in combination with the continuous release of the testosterone from the pellet may have been the cause of the aggressive/fighting behavior.

Experiment 2. Mean concentrations of testosterone are illustrated in figure 2. Testosterone concentrations, as expected, were greater when heifers were implanted with twice as many silicone implants and testosterone concentrations gradually declined with time. This decline was expected for two reasons: 1) heifers were increasing in weight therefore less hormone was being administered per kg body weight, and 2) less crystalline hormone was within the implant because of secretion and therefore less internal implant surface area to the testosterone propionate was available for diffusion. Testosterone concentrations fell to pre-treatment concentrations within 2 days after silicone implant removal. Synovex® H compressed pellet implants elevated testosterone concentrations but concentrations were four times more variable among animals within sampling days.

As reported in table 1, more heifers administered the two 15 cm implants at the onset of the study remained anovulatory during the study. This suppression on fertility was not detected in the other groups. The testosterone propionate and Synovex® H implants have previously been demonstrated to have anabolic effects and feed efficiency effects in feedlot heifers (8).

TABLE 1. Effect of Testosterone Propionate Implants on Ovarian Cyclicity.

Group	Anovulatory	Days to First Increase in Progesterone > 1.5 ng/ml ^c
Untreated	2/12 ^{a,b} (17 %)	100.0 ± 17.7 ^d
Synovex® H	1/12 ^a (8 %)	74.1 ± 11.5
TP ^e (1 + 1 15 cm implants) ^f	1/12 ^a (8 %)	91.1 ± 14.3
TP (2 15 cm implants)	6/12 ^b (50 %)	90.9 ± 22.6

^{a,b} Values with different superscripts differ (P < .05).
^c Only for heifers that became ovulatory.
^d Standard error.
^e Testosterone propionate.
^f Heifers received 1 15 cm implant on day 0 and a second 15 cm implant on day 84).

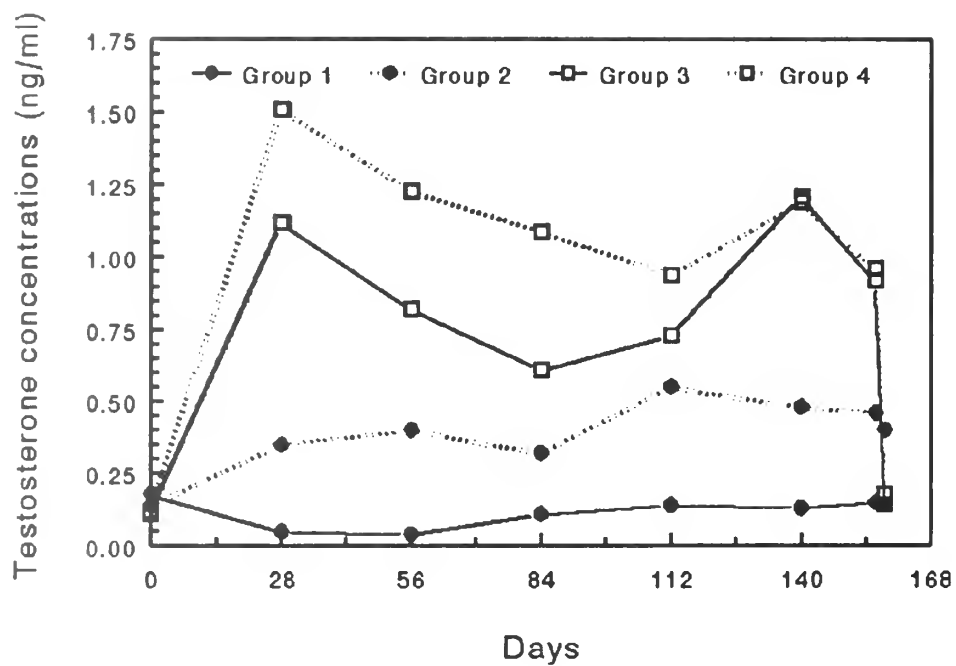


Figure 2. Blood testosterone concentrations in untreated heifers (group 1), heifers administered testosterone propionate compressed pellets (one implant on day 0 and another on day 84-group 2), heifers implanted testosterone propionate/silicone implants (one 15 cm implant on day 0 and another on day 84-group 3; two 15 cm implants on day 0-group 4).

Experiment 3. As expected, the testosterone propionate implants were effective in elevating testosterone concentrations for an extended period of time (table 2). Fewer ($P < .01$) testosterone propionate implanted heifers became pregnant during the breeding season than control heifers (table 2). Progesterone concentrations were non-statistically ($P > .10$) reduced in testosterone propionate treated heifers. The majority of the testosterone propionate treated heifers that did not become pregnant (89 %; table 2) had progesterone concentrations suggesting that the treatment suppressed ovarian cyclicity. Heifers in both groups that became pregnant calved at similar times during the calving season. Closer examination of the testosterone concentration in the heifers that became pregnant vs those that did not become pregnant revealed an effect ($P < .05$) of testosterone concentrations. Testosterone concentrations on day 39 in heifers that became pregnant (2.97 ng/ml) were lower ($P < .05$) than in heifers that did not become pregnant (4.19 ng/ml).

Testosterone propionate treatment had no effect on the sex of the resulting offspring. At 13 months of age all heifer offspring, treated and untreated, were cyclic and 6 of the 7 heifer offspring became pregnant (table 2). This absence of male phenotype in the heifers was an important finding since these heifers were exposed to a constant amount of testosterone beginning at conception. Therefore, exposure to a controlled release of testosterone did not induce male phenotype. In this experiment there was no question that testosterone was present throughout the "critical period."

Experiment 4. Results (summarized in table 3) demonstrate that prenatal androgenization clearly had no adverse affects on reproductive function. In fact the first service synchronized pregnancy rate was higher ($P < .05$) for the prenatally androgenized heifers than for the control heifers. The fertility during the entire breeding season was similar between untreated and prenatally androgenized females. The increased fertility detected for the first synchronized breeding may have been caused by a hastening of puberty in the prenatally androgenized females. This may be an indirect effect, however, since it is well established that the major controlling factor for the onset of puberty in ruminants is weight. We have previously demonstrated that prenatally androgenized females grow more rapidly (4, 6). However, other causes, such as direct effects, may be involved.

The purpose of these studies was first and foremost to demonstrate that controlled delivery of testosterone was necessary to evoke prenatal androgenization without phenotypic masculinization. Previously, all prenatally androgenized genotypic females that grew more rapidly were phenotypically male (11, 16, 19). All studies in which testosterone propionate was administered via implants produced phenotypic females that had enhanced growth and carcass characteristics (3, 4, 6, 7) with one exception (1). Clarke et al. (1) administered testosterone via compressed tablets and the resulting female offspring were phenotypically male. The cause of this variation, as demonstrated herein, is that compressed pellets do not exhibit the controlled delivery profile as silicone implants. When compressed pellets were administered, a short term spike, similar to a peak from an injection, resulted. Hence, implantation of the

compressed pellets provided therapy similar to injection therapy. Therefore, the only method to produce prenatally androgenized female offspring without masculinization is to administer the androgen such that peaks and valleys in blood concentrations are avoided, i.e. controlled delivery.

Other factors, besides delivery profile, mentioned in the introduction included dosage, timing, and androgen used. DeHaan et al. (5) used a synthetic androgen and obtained poor results. Therefore, currently it is suggested that only testosterone or testosterone esters be used for prenatal androgenization. More research is needed to determine the minimal and maximal dosage. However, since phenotypic masculinization is obtained with injections and compressed pellets, higher doses used, even in a controlled delivery format, will likely cause phenotypic masculinization. Time of initiation and duration of therapy are important factors. Based on the literature, we conclude that therapy should be initiated by about day 30 to 60 in sheep and by day 40 to 80 in cattle and be continued for approximately three weeks or more.

Other findings in these studies were 1) that prenatal androgenized heifers have a higher fertility and 2) that a controlled delivery of testosterone propionate will cause sterility in the treated heifers if the dosage is sufficiently elevated. We have not previously seen a sterility effect in treated cows (4, 6) because we have only treated pregnant cows. The enhanced fertility rates in the prenatal androgenized heifers is another advantage of prenatally androgenizing female offspring (both those intended for the feedlot and those used as replacement heifers).

REFERENCES

1. Clarke, I.J., R.J. Scaramuzzi, and R.V. Short. Effects of testosterone implants in pregnant ewes on their female offspring. *J. Embryol. Exp. Morph.* 36:87-99 (1976).
2. Christensen, D.A. and D.J. Kesler. Passage of testosterone, testosterone propionate and testosterone enanthate from silastic implants and the retention of testosterone once it enters the blood of ewes. *Anim. Reprod. Sci.* 7:531-536 (1984).
3. DeHaan, K.C., L.L. Berger, D.J. Kesler, F.K. McKeith, D.L. Thomas, and T.G. Nash. Effect of prenatal androgenization on lamb performance, carcass composition and reproductive function. *J. Anim. Sci.* 65:1465-1470 (1987).
4. DeHaan, K.C., L.L. Berger, D.J. Kesler, F.K. McKeith, D.B. Faulkner, and G.F. Cmarik. Effect of prenatal androgenization on growth performance and carcass characteristics of steers and heifers. *J. Anim. Sci.* 66:1864-1870 (1988).

5. DeHaan, K.C., L.L. Berger, D.J. Kesler, F.K. McKeith, and D.L. Thomas. Effect of prenatal trenbolone acetate treatment on lamb performance and carcass characteristics. *J. Anim. Sci.* 68:3041-3045 (1990).
6. DeHaan, K.C., L.L. Berger, D.J. Kesler, F.K. McKeith, D.B. Faulkner, G.F. Cmarik, and R.J. Favero. Effects of prenatal testosterone treatment and postnatal steroid implantation on growth performance and carcass traits of heifers and steers. *J. Anim. Sci.* 68:2198-2207 (1990).
7. DeHaan, K.C., L.L. Berger, P.J. Bechtel, D.J. Kesler, F.K. McKeith, and D.L. Thomas. Effect of prenatal testosterone treatment on nitrogen utilization and endocrine status of ewe lambs. *J. Anim. Sci.* 68:4100-4108 (1990).
8. Faulkner, D.B., F.K. McKeith, L.L. Berger, D.J. Kesler, and D.F. Parrett. Effect of testosterone propionate on performance and carcass characteristics of heifers and cows. *J. Anim. Sci.* 67:1907-1915 (1989).
9. Gorski, R.A. Sexual dimorphisms of the brain. *J. Anim. Sci.* 61(Suppl.):38.
10. Gorski, R.A. and C.D. Jacobson. Sexual differentiation of the brain. *Front. Horm. Res.* 10:1-14 (1982).
11. Hamernik, D.L., S.Y. McFarland, D. de Avila, S.R. Becker, and J.J. Reeves. Endocrine and body growth traits in heifers exposed to testosterone-propionate during early fetal development. *J. Anim. Sci.* 64:1858-1866 (1987).
12. Kesler, D.J. Novel approaches and applications of steroid hormone delivery via poly(dimethylsiloxane). *Applied Bioactive Polymeric Materials* (C.G. Gebelein, C.E. Carraher, Jr., and V.R. Foster, eds.), Plenum Press, NY, pp. 125-137 (1988).
13. Kesler, D.J., H. Khazali, and R.J. Favero. Quantification of steroids via a polymer linked second antibody immunoassay system: methods of linking anti-rabbit IgG to poly(styrene). *Progress in Biomedical Polymers* (C.G. Gebelein and R.L. Dunn, eds.), Plenum Press, NY, pp. 157-170 (1990).
14. Kesler, D.J., R.J. Favero, and T.R. Troxel. A comparison of hydron and silicone implants in the bovine norgestomet and estradiol valerate estrus synchronization procedure. *Drug Development and Industrial Pharmacy* (In Press).
15. Kesler, D.J., T.R. Troxel, D.L. Vincent, N.S. Scheffrahn, and R.C. Noble. Detection of estrus with cows administered testosterone via injections and/or silastic implants. *Theriogenology* 15:327-334 (1981).

16. Klindt, J., T.G. Jenkins, and J.J. Ford. Prenatal androgen exposure and growth and secretion of growth hormone and prolactin in ewes postweaning. *Proc. Exp. Biol. Med.* 185:201-205 (1987).
17. MacLusky, N.J., and F. Naftolin. Sexual differentiation of the central nervous system. *Science* 211:1294-1303 (1981).
18. Marit, G.B., N.S. Scheffrahn, T.R. Troxel, and D.J. Kesler. Sex behavior and hormone responses in ewes administered testosterone propionate. *Theriogenology* 12:375-381 (1979).
19. Putney, D.J., W.E. Beal, and G.A. Good. The effect of prenatal androgen exposure on sexual differentiation and growth hormone secretion in female calves. *10th Int. Congress on Reprod. and Artificial Insemination* 2:5 (1984).
20. Scheffrahn, N.S., B.S. Wiseman, R.A. Nowak, and D.J. Kesler. Induction of male sex behavior in ewes with silastic implants containing testosterone propionate. *Theriogenology* 18:1-15 (1982).
21. Sinkula, Anthony A. Methods to achieve sustained drug delivery. In: *Sustained and Controlled Release Drug Delivery Systems* (J.R. Robinson, ed.), Marcel Dekker, Inc., NY (1978).
22. Steel, R.E.D. and J.H. Torrie. *Principles and Procedures of Statistics*. McGraw-Hill, NY (1980).
23. Wiseman, B.S., D.L. Vincent, P.J. Thomford, N.S. Scheffrahn, G.F. Sargent, and D.J. Kesler. Changes in porcine, ovine, bovine, and equine blood progesterone concentrations between collection and centrifugation. *Anim. Reprod. Sci.* 5:157-165 (1982).

TABLE 2. Effect of Testosterone Propionate on Blood Testosterone and Progesterone Concentrations, Genotype, and Pregnancy Rate of Treated Females and on Reproductive Function of Female Offspring.

Item	Control	Treated
Testosterone Concentrations:		
day 39 post-implantation	0.15 ng/ml	3.82 ng/ml
day 105 post-implantation	0.18 ng/ml	3.47 ng/ml
Progesterone:		
levels in pregnant heifers	6.95 ng/ml	4.97 ng/ml
number of non-pregnant heifers < 1.5 ng/ml	1/ 1	8/ 9 (89%)
Total Pregnancy Rate (%)	11/12 ^a (92%)	4/13 ^a (31%)
Mean Day of Birth for Offspring	Feb. 10	Feb. 17
Offspring Genotype:		
males	7	1
females	4	3
Offspring:		
Ovarian Cyclicity Status	4/4 (100%)	3/3 (100%)
Total Pregnancy Rate	4/4 (100%)	2/3 (67%)

^a Values differ (P < .05).

TABLE 3. Effect of Prenatal Androgenization^a on Reproductive Performance of Beef Heifers

Trial	Control		Treated	
First Service Synchronized Pregnancy Rate ^b				
1	21/ 65	(32%)	23/50	(46%)
2	14/ 41	(34%)	16/30	(53%)
Combined	35/106 ^c	(33%)	39/80 ^c	(49%)
Total Pregnancy Rate				
1	47/ 66 ^d	(71%)	40/50	(80%)

^a Treated heifers were administered testosterone propionate prenatally.

^b Pregnancy rate to the Syncro-Mate B[®] synchronized first service.

^c Values differ (P < .05).

^d One heifer lost her Syncro-Mate B[®] implant and was not used for the first service synchronized pregnancy rate but was included in the total pregnancy rate.

CAUSES OF REDUCED PREGNANCY RATES IN BEEF FEMALES ADMINISTERED PROSTAGLANDIN $F_2\alpha$ FIVE DAYS BEFORE SYNCRO-MATE B®

T.L. Steckler, T.S. Dyson, D.B. Faulkner, and D.J. Kesler

SUMMARY

The administration of $PGF_2\alpha$ five days before Syncro-Mate B® caused a delay in synchronization in 22 % of the $PGF_2\alpha$ treated heifers (vs 0 % in the control heifers). In addition, the luteal phase progesterone secretion by the corpus luteum in the $PGF_2\alpha$ treated heifers was reduced ($P < .05$) as compared to the untreated heifers. These two factors are possible causes of the reduced timed breeding pregnancy rates in cows administered $PGF_2\alpha$ five days before Syncro-Mate B® treatment.

INTRODUCTION

Last year we reported that administration of prostaglandin $F_2\alpha$ ($PGF_2\alpha$) five days before Syncro-Mate B® (SMB) reduced pregnancy rates (Machado et al., 1994). The reduction was associated with the shift of animals to an earlier stage of the estrous cycle. Cows in the second half of the estrous cycle had higher pregnancy rates than cows in the first half of the estrous cycle (Machado et al., 1994).

The objective of this study was to determine a cause (or causes) of the reduction in pregnancy rates in beef females administered $PGF_2\alpha$ five days before SMB.

PROCEDURES

Thirty-one (31) beef heifers (approximately 12 months of age) at the University of Illinois beef herd were used in this study. Heifers were bled on days -27, -16, and -11 to determine ovarian cyclicity. SMB was administered on day -11 (both the implant and the injection). Five days before SMB treatment (day -16) the heifers were randomly assigned to one of two groups. Sixteen (16) of the heifers were administered $PGF_2\alpha$ (25 mg of Lutalyse®) on day -16. The other 15 received no treatment and served as controls. Additional blood samples, as identified in figure 1, were collected to determine corpus luteum lysis to SMB treatment and subsequent corpus luteum function. See figure 1 for the schedule of treatments.

Blood samples were centrifuged within 6 hours after collection and serum stored at -20°C. Serum was assayed for progesterone concentrations via a validated progesterone ELISA (Kesler et al., 1990). Heifers were classified as cyclic or non-cyclic based on the three blood samples collected prior to SMB treatment (days -27, -16, and -11). Heifers were considered cyclic if any one or more of the three blood

samples was equal to or greater than 1.5 ng/ml of progesterone. An additional classification was made from the blood samples collected on days 0 to 21. If progesterone concentrations remained low (less than 1.0 ng/ml) from day 0 to day 17 heifers were considered to have not ovulated to the SMB synchronization. If progesterone concentrations were low (less than 1.0 ng/ml) on days 0 and 3, increased to greater than 1.0 ng/ml on day 7, and then fell to less than 1.0 ng/ml on day 14, heifers were considered to have ovulated and have shorten luteal phases or luteal dysfunction. Heifers were considered to have ovulated and have luteal phases of normal duration if progesterone concentrations were low (less than 1.0 ng/ml) on days 0 and 3, increased to greater than 1.0 ng/ml on days 7 to 14. These definitions have been previously validated (Kesler et al., 1981).

Figure 1. The schedule of treatments and blood collections.



B = Blood collection for progesterone determination.

RESULTS AND DISCUSSION

Most of the heifers (10 of the 11) that did not ovulate to the SMB synchronization were non-cyclic heifers (table 1). Overall 36 % of the heifers did not ovulate to the SMB synchronization. Thirteen (13) percent of the heifers had shorten luteal phases and these were evenly distributed among cyclic and non-cyclic heifers. The incidence of not ovulating to SMB synchronization and having shortened luteal phases was not influenced by PGF₂α treatment.

Only two of the heifers had elevated (greater than 1.0 ng/ml) progesterone concentrations at the time of implant removal. All (100 %) of the heifers had low (less than 0.5 ng/ml) progesterone concentrations on day 0. Therefore, SMB was effective in eliminating corpora lutea, regardless of the stage of development when administered. The two heifers that had elevated progesterone concentrations on day -2 (the day of implant removal) were in the PGF₂α treatment group. These progesterone concentrations were two standard deviations greater than the progesterone concentrations for the untreated heifers on the same day. In addition, progesterone concentrations for these two heifers was two standard deviations lower

than the control heifers on day +7. This suggests that these heifers had a delayed synchronization response to the SMB. Based on the progesterone concentrations this delay was approximately one day delay. However, this would significantly affect pregnancy rates to a timed breeding and occurred in 22 % (2 of 9) of the PGF₂α treated heifers vs 0 % of the control heifers.

Progesterone concentrations for the 16 heifers considered to have luteal phases of normal duration are illustrated in figure 2. The control and PGF₂α treated non-cyclic heifers were combined due to low numbers (3 control and 1 treated). In general, the progesterone secretion during the SMB synchronized luteal phases for PGF₂α treated heifers was suppressed as compared to control heifers. This suppression was apparent during the entire luteal phase. The area under the response curve demonstrates that this suppression was significant ($P < .05$) and that the suppressed progesterone secretion was similar ($P > .25$) to heifers induced to have the first pubertal estrous cycle (table 2).

CONCLUSION

This study was conducted to determine causes of reduced pregnancy rates in females administered PGF₂α five days before SMB treatment. Two factors (delayed synchronization and reduced luteal phase progesterone secretion) were identified in this study.

REFERENCES

- Kesler, D.J., H. Khazali, and R.J. Favero. 1990. Quantification of steroids via a polymer linked second antibody immunoassay: methods of linking anti-rabbit IgG to poly(styrene). In: Progress in Biomedical Polymers. Ed., C.G. Gebelin and R. Dunn. Plenum Publishing Co., New York, pp. 157-170.
- Kesler, D.J., P.G. Weston, C.A. Pimentel, T.R. Troxel, D.L. Vincent, and J.E. Hixon. 1981. Diminution of the in vitro response to luteinizing hormone by corpora lutea induced by gonadotropin releasing hormone treatment of postpartum suckled beef cows. J. Anim. Sci. 53:749-754.
- Machado, R., D.B. Faulkner, and D.J. Kesler. 1994. Effects of the stage of the estrous cycle on the calving rate of postpartum beef cows submitted to estrus synchronization with Syncro-Mate B®. Beef Research Report, pp. 77-82.

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Table 1. Number of cyclic and non-cyclic heifers that did not, or that ovulated and had shortened luteal phases or luteal phases of normal duration.

	Did Not Ovulate	Shortened Luteal Phases	Luteal Phases of Normal Duration
Cyclic:			
Control	1	1	4
PGF ₂ α Treated	0	1	8
Non-cyclic:			
Control	5	1	3
PGF ₂ α Treated	5	1	1
Combined:			
Control			
(n)	6	2	7
(%)	40 %	13 %	47 %
PGF ₂ α Treated			
(n)	5	2	9
(%)	31 %	13 %	56 %
All Heifers (%)	36 %	13 %	52

Table 2. Area under the progesterone response curve for non-cyclic, and control and PGF₂α treated heifers that were considered to have ovulated and have luteal phases of normal duration.

Group	n	AUC ^a	SE ^b
Non-cyclic	4	37.23 ^c	3.26
Cyclic:			
Control	4	48.39 ^d	2.74
PGF ₂ α Treated	8	37.52 ^c	3.10

^a Area under the curve was the progesterone concentrations on days 0 to day 17 (the luteal phase subsequent to SMB synchronization).

^b Standard error.

^{c,d} Values with difference superscripts differ (P < .05).

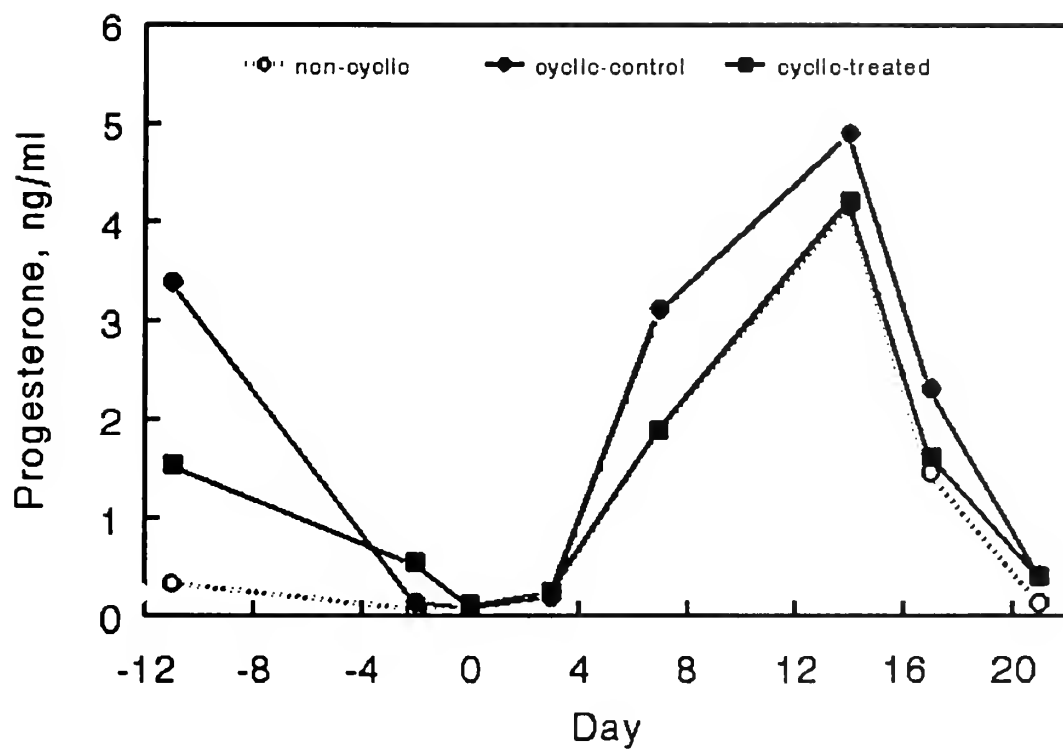


Figure 2. Progesterone concentrations (ng/ml) of non-cyclic heifers and cyclic heifers after no treatment (control) or prostaglandin $F_2\alpha$ treatment (treated).

THE EFFECT OF PROSTAGLANDIN F_{2α} TREATMENT ON CALVING DATE IN BEEF COWS BRED NATURAL SERVICE

J. W. Castree, D. B. Faulkner and D. J. Kesler

SUMMARY

Seventy-six, multiparous, Angus x Simmental crossbred cows were used to determine the effect of a single prostaglandin F_{2α} (PGF) injection on subsequent calving date. Thirty-seven cows were randomly chosen to receive an injection of 25 mg PGF on day one of a seventy day breeding season. Control cows (n = 39) received no treatment. All cows were exposed to fertile bulls in single sire breeding pastures containing eleven to sixteen cows per pasture. Conception rates for treated and control cows were 100% and 97% respectively. There was no difference in calving date (P = .61) between control and PGF treated cows. Least squares means for calving date for treated and control cows were day 18.6 and day 20.4 respectively. A single injection of PGF at the begining of the breeding season has no effect on subsequent calving date in this study.

INTRODUCTION

Estrous synchronization allows cattlemen the opportunity to exert some control on when and how females are bred. Estrous synchronization allows more females to be bred early in the breeding season. This results in more calves being born early in the calving season that will be older and heavier at weaning. Therefore many beef herds with a finite breeding season, that wean all calves on the same date, have utilized estrous synchronization in their breeding program.

The combination of estrous synchronization and artificial insemination (AI) can shorten the calving season, produce a more uniform calf crop and allow for more efficient use of labor at calving time. The use of AI among purebred breeders is widespread, however the majority of beef cows in commercial herds are bred through natural service. Many beef producers do not have the facilities, labor or training required for a successful AI breeding program. The single injection system of administering prostaglandin may be the most economical form of estrous synchronization for those beef herds which are bred natural service.

The objective of this trial was to determine the effects of a single injection of PGF at the begining of the breeding season on calving date in a natural service breeding system.

MATERIAL AND METHODS

Seventy-six multiparous, suckled, Angus x Simmental crossbred cows were randomly assigned to either a treated (n = 37) or control group (n = 39). Treated cows were injected intramuscularly with 25 mg PGF (Lutalyse; The Upjohn Co., Kalamazoo, MI)

on the first day of a seventy day breeding season. At the beginning of the breeding season, cows weighed 1184 ± 141 lb and had a body condition score (BCS) of $5.6 \pm .6$. Cows were randomly sorted into single sire breeding groups consisting of eleven to fifteen cows. Cows were pasture exposed to bulls for 70 days. Bulls were one to three years of age and had passed a breeding soundness exam. Cattle rotationally grazed either tall fescue/red clover or tall fescue/alfalfa pastures throughout the breeding season. Pregnancy was confirmed via rectal palpation following calf weaning. The first day of the calving season was 285 days after the bulls were put with the cows.

RESULTS AND DISCUSSION

Conception rate was not influenced by PGF treatment. Control cows achieved a 97% conception rate while cows receiving the PGF treatment had a 100% conception rate. Body condition may be an indicator of potential reproductive performance of beef cows. Cows were in good body condition during their last trimester of pregnancy, with an average BCS for PGF treated and control cows of $6.0 \pm .7$ and $5.8 \pm .6$ respectively. At the beginning of the breeding season the average BCS for PGF treated cows was $5.8 \pm .6$ while control cows had an average BCS of $5.5 \pm .6$. Body condition score before parturition and at the beginning of the breeding season, are the dominant factors influencing subsequent pregnancy rates (Selk et al., 1988).

There was no difference in calving date ($P = .61$) between control and PGF treated cows. Least squares means for calving date during the 75 day calving season for PGF treated and control cows were day 18.6 ± 2.4 and day 20.4 ± 2.4 respectively. However, 10% more cows in the PGF treated group calved during the first twenty-one days of the calving season (45.9% vs 35.9%) than in the control group of cows. Stage of the estrous cycle at the time of PGF treatment will influence the efficacy of treatment. Prostaglandin has no effect early in the cycle before the corpus luteum is developed, nor late in the cycle when the corpus luteum is regressing. The stage of the estrous cycle at the initiation of an estrous synchronization procedure, and more importantly the interval between ovulations, has an effect on the fertility at the synchronized estrus (Kesler et al., 1991).

CONCLUSIONS

A single PGF injection at the beginning of the breeding season has no effect on subsequent calving date of lactating beef cows bred natural service. Determination of reproductive status (cyclic or anestrous) prior to PGF injection would eliminate noncycling females from treatment. By not injecting noncycling animals unnecessary costs could be avoided.

REFERENCES

- Kesler, D. J., L. L. Berger, D. B. Faulkner and R. J. Favero. 1990. The effect of melengestrol acetate on the fertility of beef heifers. Illinois Beef Res. Rep. 1991:66-67.
- Selk, G. E., R. P. Wettemann, K. S. Lusby, J. W. Oltjen, S. L. Mobley, R. J. Rasby and J. C. Garmendia. 1988. Relationship among weight change, body condition and reproductive performance of range beef cows. J. Anim. Sci. 66:3153.

FERTILITY OF SYNCHRONIZED EARLY POSTPARTUM SUCKLED BEEF COWS WITH NORGESTOMET/SILICONE IMPLANTS

D.J. Kesler, R. Machado, D.B. Faulkner, and T.G. Nash

SUMMARY

The use of norgestomet implants twice postpartum not only synchronized a second postpartum timed estrus but also enhanced postpartum fertility.

INTRODUCTION

One major limitation in beef cattle reproduction is postpartum anestrous. Reproduction is delayed after parturition because of two reasons. First, the endocrine system needs time (approximately two weeks) to redevelop the capability of secreting the reproductive hormones necessary for reoccurring estrous cycles. Second, suckling suppresses the secretion of luteinizing hormone (LH) from the anterior pituitary gland. This suppression on LH suppresses follicular growth and ovulation. This block on ovarian cycles occurs for varying periods of time and is influenced by genetics, milk production, and the frequency of suckling.

A procedure to override the suckling induced suppression on ovarian cycles and induce fertile ovarian cycles is important in order to improve beef cattle production. This study was conducted to determine if the combined use of the Syncro-Mate B® synchronization procedure followed by re-synchronization with norgestomet implants would hasten fertile ovulations postpartum.

PROCEDURES

Over two years (1992 and 1993) 118 postpartum suckled beef cows (7 to 112 days postpartum) were synchronized with Syncro-Mate B® followed with a 9 day norgestomet implant beginning 12 days after the first timed AI. All cows with progesterone < 1.5 ng/ml (at the time of implant removal) were artificially inseminated 23 days after the first AI (48 hours after implant removal). Cows were divided into 2 groups prior to treatment initiation and pregnancy rates determined at calving. The two groups were based on the stage postpartum when the SMB synchronized AI was done. Cows were either less than 42 days postpartum at the time of the first AI (group 1) or were 42 days or greater postpartum (group 2) at the time of the first AI.

Progesterone concentrations in the plasma were determined using an ELISA as described by Kesler et al. (1990).

RESULTS

Cows < 42 d postpartum becoming pregnant at the first AI averaged 29 days postpartum (19 to 41 days). Days postpartum for the cows < 42 days postpartum at initiation that became pregnant to the second AI averaged 42 days postpartum. Pregnancy rate to the second AI (only for cows < 42 days postpartum re-bred) of 53% (after two implantation periods) was greater ($P = .11$) than the pregnancy rate of 27 % for cows at an equal stage postpartum after only one implantation. The cumulative pregnancy rate from the first and second AI (23 day period) was high and equal ($P > .10$) for both stages postpartum.

Table 1. Pregnancy Rate for Suckled Beef Cows Administered Syncro-Mate B for Synchronization (First AI) and Norgestomet/Silicone Implants for Re-Synchronization (Second AI).

Item	Days Postpartum at First AI	
	Less than 42 d	42 d and greater
number	30	88
number pregnant:		
first AI	8 (27%) ^{a,f}	44 (50%)
second AI	9 (53%) ^{b,c,d}	16 (48%) ^c
cumulative ^e	17 (57%)	60 (68%)

^a Days postpartum to pregnancy for these eight cows was 29.3 days (19 to 41 days).

^b Days postpartum to pregnancy for these 9 cows was 42.0 days (33 to 59 days).

^c The percentage is based on the number pregnant divided by the number bred at the second AI.

^d The pregnancy rate for the other cows at a similar time postpartum (33 to 59 days) with only one previous norgestomet implantation period was 27 % (6/22) ($P < .11$).

^e The cumulative is the number (percentage of total) pregnant from the first two timed AI's (the first 23 days of the breeding season).

^f Differs ($P < .05$) from the first AI pregnancy rate for cow 42 days or greater postpartum.

DISCUSSION

The re-synchronization program has been successfully used previously (Favero et al., 1993). Although pregnancy rates at the first AI for the cows less than 42 days postpartum were low, actually these are very good pregnancy rates for cows at this early stage postpartum. The pregnancy rate at the second AI are equal to cows later postpartum suggesting that the double norgestomet implantation effectively reestablishes the reproductive system for successful reproduction. Additional studies will be conducted to determine the optimum time of implantation of the re-synchronization implant.

CONCLUSION

The use of Syncro-Mate B® followed by re-synchronization with norgestomet implants enhanced postpartum fertility in suckled beef cows.

REFERENCES

- Favero, R.J., D.B. Faulkner, and D.J. Kesler. 1993. Norgestomet implants synchronize estrus and enhance fertility in beef heifers subsequent to a timed artificial insemination. *J. Anim. Sci.* 71:2594-2600.
- Kesler, D.J., H. Khazali, and R.J. Favero. 1990. Quantification of steroids via a polymer linked second antibody immunoassay: methods of linking anti-rabbit IgG to poly(styrene). In: *Progress in Biomedical Polymers*. Ed., C.G. Gebelin and R. Dunn. Plenum Publishing Co., New York, pp. 157-170.

OVULATION RATE AND EMBRYO QUALITY OF SUPEROVULATED BEEF HEIFERS SUPPLEMENTED WITH AN ORGANIC CHELATED MINERAL

R. B. Angus, D. D. Buskirk, T. G. Nash and D. B. Faulkner

SUMMARY

Eighty-eight yearling commercial heifers were used in two separate trials to determine the effects of supplementation with an organic chelated mineral on ovulation rate and embryo quality. Heifers were fed a roughage based diet and supplemented daily with a corn based supplement containing 5 g of either an organic chelated mineral (O) or an inorganic mineral (I). Heifers were synchronized and blood samples taken to identify those which were pubertal. Pubertal heifers were superovulated, bred by artificial insemination and embryos were recovered nonsurgically. Response to superovulation was not different due to treatment. Heifers consuming the chelated mineral produced more ($P = .05$) recoverable ovum than the control. Embryo number and quality were not significantly different between treatments. Heifer weight gain during the trial was also unaffected by treatment.

INTRODUCTION

One of the more recent techniques for exploitation of superior beef genetics is embryo transfer. The transfer of embryos from matings of elite sires and dams can produce large numbers of genetically superior animals in shortened period of time. Embryo transfer is a procedure which requires a sizable financial commitment. A return on this investment requires that producers maximize the number of high quality embryos secured from each donor female.

Proper mineral nutrition is critical for normal function of reproductive processes in the beef cow. Recent research suggests chelation of certain minerals can increase their availability to the animal. Increased availability of certain minerals may influence the ovulation rate of superovulated beef females and increase the percentage of these ova that develop into viable, transferable embryos. The objectives of this study were to determine the effects of organic chelated mineral supplementation on ovulation rate and embryo number and quality of superovulated beef heifers.

MATERIALS AND METHODS

Trial 1

Twenty-three Angus and fifteen Angus x Simmental heifers, 11 ± 1 mo of age, were randomly allotted by breed to two dietary treatments. The trial was conducted at the University of Illinois Beef Research Facility, Urbana, IL., from November 30, 1993 to January 28, 1994. Heifers were fed a corn silage based diet and a corn based supplement (.227 kg) which included either an organic chelated mineral (O) or an inorganic mineral (I) at the rate of 5 g mineral per day for 60 days.

Estrus was synchronized with Syncro-Mate-B® (SMB). The SMB procedure consists of an intramuscular injection of norgestomet (3.0 mg) and estradiol valerate (5.0 mg) in a sesame oil and benzyl alcohol (10%) carrier and a hydron implant that contains 6.0 mg of norgestomet. The implant was inserted subcutaneously into the convex surface of the ear. The implants were removed at the end of nine days. To identify heifers that were pubertal, blood samples were collected 7 d after implant removal via jugular venipuncture and immediately placed on ice to prevent progesterone metabolism (Wiseman et al., 1982). Progesterone concentrations were determined by a validated enzyme immunoassay as described by Kesler et al. (1990). Samples with progesterone concentrations ≥ 1.5 ng/ml were considered to be from heifers exhibiting estrous cycles. Ten heifers from each treatment were found to be exhibiting estrous cycles. The remaining twenty heifers received twice daily single i.m. injections of follicle stimulating hormone (FSH) to stimulate superovulation. FSH dosage was 5, 5, 4, 4, 3, 3, 2, and 2 mg per injection respectively. Heifers that were superovulated were administered 25 mg and 15 mg of PGF_{2 α} with each of the last two FSH injections respectively. Heifers were inseminated with frozen semen from a single collection of one sire 36 and 48 h following the last PGF_{2 α} injection.

Embryos were collected nonsurgically on d 7 following the first insemination. Embryos were recovered from flushing under a stereomicroscope. Ova were counted and embryos graded by examination of morphological appearance with the microscope. Embryos were identified as either morulae or blastocyst. Those with no visible imperfections were graded as excellent (Grade 1), those with a few extruded blastomeres as fair (Grade 2), those with severe imperfections as poor (Grade 3), and those not viable (Degenerate). Collection was performed by a certified veterinarian and grading by an accredited embryologist.

Response to FSH was analyzed using the General Linear Models procedures of SAS (1985) with animal as the experimental unit. Further analysis was conducted on only those heifers that responded to FSH treatment. The model statement contained total ova, total embryos, grade 1 embryos, grade 2 embryos, grade 3 embryos, degenerate embryos, unfertilized ova, and weight gain as dependent variables and treatment as the independent variable.

Trial 2

Fifty yearling Angus and Angus x Hereford heifers (386 ± 47 kg) were randomly allotted to two dietary treatments. The trial was conducted at the University of Illinois Beef Research Facility, Urbana, IL., from October 9, 1994 to December 12, 1994. Heifers were fed an ensiled corn shuck based diet and a corn based supplement (.454 kg) which included either an organic chelated mineral (O) or an inorganic mineral (I) at the rate of 5 g mineral per day for 60 days.

Estrus synchronization, superovulation, breeding and embryo recovery were performed according to the same procedures as in Trial 1. Twenty-two heifers from each treatment were found to be exhibiting estrous cycles and were used for the superovulation procedure.

RESULTS

No trial by treatment interaction was detected ($P > .15$) and therefore the trials were combined for data analysis. Forty-five of sixty-four cyclic heifers (21 I and 24 O) responded to superovulation treatment and provided recoverable ovum. The results of embryo recovery are listed in Table 1. Superovulatory response was not significantly different between treatments. Heifers consuming the chelated mineral produced more ($P = .05$) total ovum than the controls (6.17 vs. 4.24). Average recovery of total embryos and Grade 1, 2 and 3 embryos were similar between treatments. The number of degenerate embryos from O heifers tended to be higher ($P = .09$) than I heifers. The number of unfertilized ovum from O heifers also tended to be higher ($P = .07$) than the control. This trend was expected as total ova number was higher for O heifers and embryo number was similar between treatments. Heifer weight gain during the trial period was also unaffected due to treatment.

CONCLUSIONS

The total number of ovum recovered was significantly greater for those heifers consuming the organic chelated mineral. This indicates that ovulation rate is improved by the chelated mineral. Neither the number nor the quality of embryos recovered were affected by supplementation with an organic chelated mineral.

LITERATURE CITED

- Kesler, D.J., H. Khazali and R. J. Favero. 1990. Quantification of steroids via a polymer linked second antibody enzyme immunoassay system. In: Progress in Biomedical Polymers. Ed., C.G. Gebelein and R. L. Dunn, Plenum Publishing Co., New York, NY, p.157-170.
- SAS. 1985. SAS User's Guide. SAS Inst., Inc., Cary, NC.
- Wiseman, B. S., D. L. Vincent, P. J. Thomford, N. S. Scheffrahn, G. S. Sargent and D. J. Kesler. 1982. Changes in porcine, ovine, bovine, and equine blood progesterone concentrations between collection and centrifugation. Anim. Reprod. Sci. 5:157.

TABLE 1. RESPONSE TO SUPEROVULATION AND EMBRYO RECOVERY RESULTS^a

	Treatment		P Value
	Control (I)	Chelated (O)	
Response to FSH	21/32 (66%)	24/32 (75%)	.41
Embryos	2.42	2.71	.74
Grade 1	1.62	1.38	.67
Grade 2	0.67	0.63	.88
Grade 3	0.10	0.08	.90
Degenerate	0.10	0.02	.09
Unfertilized Ova	1.81	3.46	.07
Total recovered	4.24	6.17	.05

^a Treatment means for heifers responding to FSH

The Effect of Norgestomet Implantation on the Pregnancy Rate of Embryo Transfer Recipient Cows

D.J. Kesler, T.G. Nash, D.B. Faulkner, and W. Pollitt

SUMMARY

Norgestomet implants administered to recipient cows at embryo transfer, and left in situ for 14 days, enhanced transferred embryo survival. Pregnancy rates were 29% and 44% for the control and norgestomet treated cows, respectively. In addition, norgestomet treated non-pregnant cows had a more synchronized return estrus than control cows.

INTRODUCTION

Norgestomet implantation, after Syncro-Mate B® synchronization, has been previously used to obtain a second synchronized estrus in cows not conceiving to the Syncro-Mate B® timed AI (Favero et al., 1993). Data obtained in both beef cows and heifers demonstrate that this procedure is very efficacious in synchronizing non-pregnant beef females (Favero, 1992). In addition, Favero et al. (1993) demonstrated that the pregnancy rate to the Syncro-Mate B® synchronization (the first AI) is enhanced in beef heifers by subsequent norgestomet implantation. Overall, fertility was increased from 21 % for non-implanted heifers (n = 42) to 50 % for norgestomet implanted heifers (n = 40)(Favero et al., 1993).

This study was conducted as a preliminary study to determine if enhancement to Syncro-Mate B® synchronization could be obtained in embryo transfer recipient cows.

PROCEDURES

Thirty-two beef cows were synchronized with Syncro-Mate B®. Nine days after implant removal (day 7 of the synchronized estrous cycle) embryos (all grade 1 or 2 embryos) were placed in the cows. At the time of embryo placement cows were randomly assigned to one of two groups. At the time of embryo placement (day +7) eighteen (18) of the cows were administered two 6 mg norgestomet/silicone implants (Kesler et al., 1994). One implant was placed in the right ear and one implant was placed in the left ear. The other 14 cows received no implants and served as controls. The norgestomet implants were left in situ for 14 days (removed on day 21).

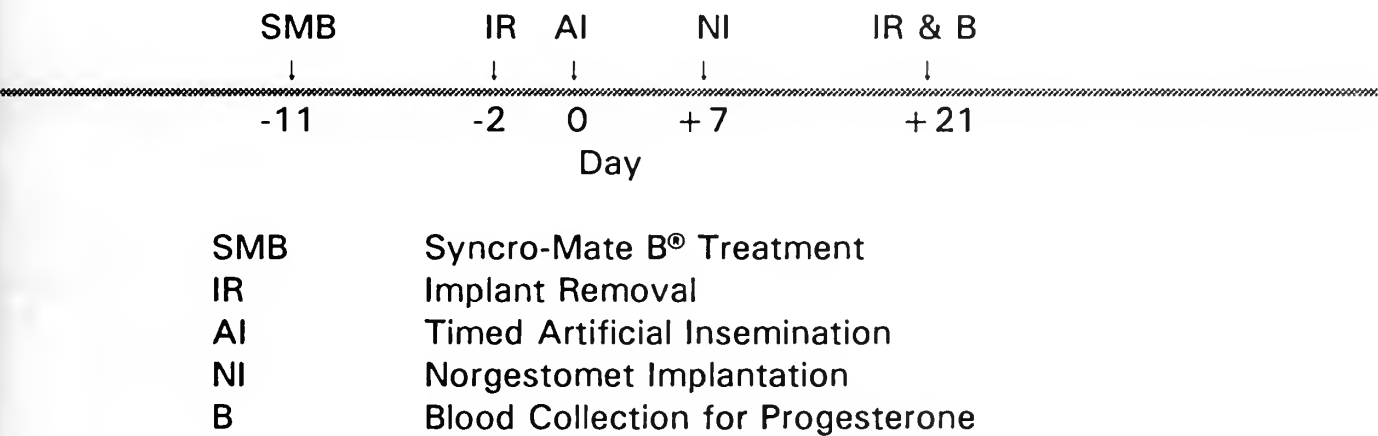
At implant removal cows were bled and serum collected was assayed for progesterone concentrations via a validated ELISA (Kesler et al., 1990). Cows with

progesterone concentrations of 1.5 ng/ml or greater were classified as pregnant and cows with less than 1.5 ng/ml were classified as non-pregnant.

Cows were also monitored for estrus twice daily (early morning and late evening) beginning at embryo placement and continuing for 60 days. Cows were bred via the a.m./p.m. rule beginning after embryo placement.

Pregnancy was determined per rectum 80 to 110 days after the first synchronized timed AI.

Figure 1. Schedule of Treatments.



RESULTS AND DISCUSSION

This study was conducted as a preliminary study to determine feasibility of using norgestomet treatment to enhance pregnancy rate of embryo transfer recipients. Pregnancy rates were higher for norgestomet treated cows than for control cows (table 1). In addition, if cows did not maintain pregnancy to the embryo transfer, more cows were subsequently detected in estrus and the return estrus was more synchronized for the norgestomet treated cows than for the control cows (table 1).

Overall, the progesterone concentrations were 94 % accurate in diagnosing pregnancy (table 2). As previously reported, the low progesterone diagnosis of open cows was 100 % correct.

CONCLUSION

The results from this preliminary study suggest that further controlled studies, either on campus or by collaboration off campus, are warranted. Minimal addition work is required with this procedure. The only additional animal handling is on day +21 in order to remove the implants. The advantages for utilizing this procedure include higher embryo survival rate and improved synchronization at the return estrus. Analyzing blood progesterone concentrations on day +21 are not necessary but are highly effective particularly for identifying open cows.

REFERENCES

- Favero, R.J. 1992. Methods of fertility enhancement and control of beef females. Ph.D. Thesis. University of Illinois, 151 pp.
- Favero, R.J., D.B. Faulkner, and D.J. Kesler. 1993. Norgestomet implants synchronize estrus and enhance fertility in beef heifers subsequent to a timed artificial insemination. *J. Anim. Sci.* 71:2594-2600.
- Kesler, D.J., H. Khazali, and R.J. Favero. 1990. Quantification of steroids via a polymer linked second antibody enzyme immunoassay: methods of linking anti-rabbit IgG to poly(styrene). In: *Progress in Biomedical Polymers*. Ed., C.G. Gebelein and R. Dunn, Plenum Publishing Co., NY, pp. 157-170.
- Kesler, D.J., R.J. Favero, and T.R. Troxel. 1994. A comparison of hydron and silicone implants in the bovine norgestomet and estradiol valerate estrus synchronization procedure. *Drug Development and Industrial Pharmacy* (In Press).

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Table 1. Pregnancy Rate and Estrus Response of Cows Administered Norgestomet Implants for 14 day Beginning on the day of Embryo Transfer.

	Control	Norgestomet Treated
Pregnancy Rate	4/14 (29%)	8/18 (44%)
Return Estrus	5/10 (50%)	8/10 (80%)
Synchronized		
Return Estrus ^a	5/10 (50%)	7/10 (70%)
Synchronized		
Return Estrus ^b	3/10 (30%)	7/10 (70%)

^a The period of three days of highest incidence of estrus (controls = days 18, 19, and 20; treated = days 22, 23, and 24).

^b The one day of highest incidence of estrus (controls = day 18; treated = day 23).

Table 2. Accuracy of Progesterone Concentrations at Day 21 in Diagnosing Pregnancy

	Accuracy
All Cows	30/32 (94%)
Cows With High ^a Progesterone Concentrations	12/14 (86%)
Cows With Low ^a Progesterone Concentrations	18/18 (100%)

^a Cows were considered to have high progesterone concentrations if they were 1.5 ng/ml or greater. Cows were considered to have low progesterone concentrations if they were less than 1.5 ng/ml.

PROGESTERONE AND ELECTRICAL RESISTANCE EFFECTIVELY DIAGNOSE PREGNANCY STATUS IN BEEF HEIFERS AFTER NORGESTOMET RE-SYNCHRONIZATION

F.N. Domatob, R. Machado, F.A. Ireland, D.B. Faulkner,
and D.J. Kesler

SUMMARY

Two herds of heifers ($n = 18$ and 440) were administered Syncro-Mate B for estrus synchronization and bred by AI at approximately 48 hours after implant removal. Nine of the first group and 277 of the second group were also administered a 6 mg silicone/norgestomet implant on day 12 post-AI. Implants were removed 9 days later (day 21 post-AI) and blood samples collected and analyzed for progesterone (P_4) via a validated ELISA. Additional blood samples collected from the heifers in the first group immediately before the second implantation and on d 13, 15, 17, and 19 after AI were analyzed for P_4 . Heifers in the first group were also diagnosed for pregnancy status per rectum on day 42 post-AI. Heifers in the second group were randomly assigned to 1 of 3 groups: Group 1 were control heifers and fertile bulls were included with the group 12 days post-AI and onwards, Group 2 heifers with P_4 less than 1.5 ng/ml (at the time of the second implant removal) were bred via AI approximately 48 hours after the removal of the second implant, and Group 3 heifers with electrical resistance (ER) values of less than 81 units were bred via AI about 48 hours after the second implant removal. ER values were determined for all heifers in groups 2 and 3 immediately prior to the second AI. P_4 in the first group of heifers demonstrated that norgestomet implantation had no effect ($P > .25$) on P_4 secretion of both pregnant and non-pregnant heifers. In the second group of heifers, it was determined that ER was similar ($P > .25$) to P_4 diagnosis of pregnancy status. Further, ER and P_4 diagnosis of pregnancy agreed up to 86 % of the time. Pregnancy results of heifers bred by both methods were similar ($P > .25$). In summary, both methods of diagnosing pregnancy status were similarly efficacious.

INTRODUCTION

Livestock producers synchronize estrus for many reasons. One reason is because it allows one to take advantage of the benefits of artificial insemination (AI). Syncro-Mate B (SMB), a commercial progestin (norgestomet) and estradiol (estradiol valerate) synchronization procedure, synchronizes estrus and ovulation so effectively that females can be bred at predefined period without estrus detection (2, 4, 7, 10, 11, 13). Although estrus can be effectively synchronized and females can be inseminated, this procedure does not allow producers to use more than one timed breeding. Since only 30 to 50 % of the treated cattle generally become pregnant and calve to one service, subsequent estrus detection is required if AI is to be employed

any further. This study was a continuation of earlier work done in our laboratory (4, 5) which suggested that non-pregnant cattle (to the first AI) could be synchronized a second time with a norgestomet implant permitting livestock producers to use AI for two services and therefore increase the number of AI calves.

A thorough evaluation of the effect of norgestomet on secretion of progesterone by the corpus luteum during the re-synchronization procedure has not been done. Further, all previous work has utilized progesterone concentrations at implant removal for determination of animals to be bred at the second AI. The two studies in this paper were conducted to: 1) determine if norgestomet implantation had any effect on progesterone secretion by the corpus luteum and 2) to determine if an electrical resistance reading of the fluids in the anterior vagina, which is less difficult to accomplish than progesterone determinations, could be used to effectively determine pregnancy status.

MATERIALS AND METHODS

Experiment 1. Beginning in May 1992, 18 yearling crossbred beef heifers from the Urbana Beef Unit of the University of Illinois were synchronized with Syncro-Mate B (Sanofi Animal Health, Inc., Overland Park, KS; SMB) and bred about 48 hours after implant removal. SMB treatment consisted of an intramuscular injection of 5 mg estradiol valerate and 3 mg norgestomet in sesame oil and benzyl alcohol given at time of insertion of a norgestomet ear implant. The implant was placed subcutaneously on the convex surface of the ear and left in situ for 9 days. Fourteen days after the SMB implant removal, heifers were randomly assigned to two groups. One half of the heifers (9) were implanted with matrix silicone implants containing 6 mg of norgestomet. The implants were subcutaneously implanted on the convex surface of the ear. The other one-half of the heifers received no further implants and served as controls.

Blood samples were collected from the jugular vein by venipuncture on day 12 post-AI, immediately prior to norgestomet administration. Thereafter, the heifers were bled on days 13, 15, 17, 19, and 21 after the first AI. The blood samples were centrifuged at 1000 x g within 6 hours after collection and the serum was stored at -20 °C until it was assayed (14). Progesterone concentrations of the blood serum were determined by a validated enzyme immunoassay (8).

Any heifer with progesterone concentrations greater than or equal to 1.5 ng/ml (4) on day 21 was classified pregnant and verified pregnant by per rectum examination on day 42 post insemination. Progesterone concentrations were analyzed by SAS factorial split-plot analysis of variance with day, treatment, and pregnancy status as the main effects (12). All interactions were also examined.

Experiment 2. Four hundred and forty yearling beef heifers (Angus and Angus X Hereford) weighing 252.5 ± 34.7 kg at the Dixon Spring Agricultural Station (Simpson, Illinois) were used in the study. The reproductive status of each heifer was determined by the progesterone concentrations of two blood samples collected ten days before and at time of Syncro-Mate B (SMB) treatment. Blood was collected from each heifer via jugular venipuncture and immediately stored in ice (14) until centrifugation at $1000 \times g$ which was done within 6 hours after collection. The serum samples were stored at -20°C until they were assayed. Progesterone concentrations of each serum sample was determined using a validated enzyme linked immunoassay (8). Heifers were considered cyclic if either of the two blood samples had progesterone concentrations ≥ 1.5 ng/ml.

Estrus was synchronized in all heifers using Syncro-Mate B. Any heifer that lost her implant was eliminated from the study. After 9 days, the implants were removed and all the heifers were artificially inseminated with fertile semen from commercial bull studs approximately 48 hours after implant removal.

Heifers were assigned to three groups following a random permutation table (3) 12 days after the first artificial insemination (AI). Group 1 heifers received no further implants after SMB treatment and were bred naturally by exposing the heifers to the bulls beginning 12 days and onwards after the first artificial insemination. Group 2 heifers were implanted with 6 mg norgestomet implants 12 days after the first AI and implants were left in situ for 9 days. The electrical resistance probe (Ovascan Deluxe, Animark, Inc., Aurora, CO) was inserted into the anterior vagina of each heifer to determine electrical resistance 48 hours after implant removal. Any heifer with an electrical resistance reading that did not indicate pregnancy (≤ 81 units) was artificially inseminated. Group 3 heifers received one implant each, containing 6 mg norgestomet, 12 days after the first AI. The implants were left in situ for 9 days and at removal, the heifers were bled and serum samples analyzed for progesterone concentrations. Heifers with progesterone concentrations less than 1.5 ng/ml were artificially inseminated about 48 hours after the second implant removal.

All semen used in the study came from more than one bull and was used without bias across treatment groups. Pregnancy rates were determined 9 months later at calving.

Qualitative data were analyzed by Chi-square analysis (3). Data that were analyzed included pregnancy rates to the Syncro-Mate B synchronized estrus determined from calving data 283 ± 11 days from first AI, pregnancy rates to the norgestomet implant synchronized estrus (283 ± 11 days from second AI). Pregnancy diagnosis data were analyzed as described by Fletcher et. al. (6).

RESULTS AND DISCUSSION

Experiment 1. All the heifers had high serum progesterone concentrations on day 12 (day 0 = AI) ranging from 6.75 to 9.01 ng/ml (figure 1). At 42 days after the first AI it was determined that in each group 3 heifers were pregnant and 6 were non-pregnant. By day 21 after the first AI, the six pregnant heifers had progesterone concentrations ranging from 5.67 to 10.93 ng/ml. The non-pregnant heifers all had progesterone concentrations of less than 1.0 ng/ml on day 21. Progesterone concentrations changed ($P < .01$) with time and were affected by pregnancy status ($P < .01$). Further, there was a significant ($P < .01$) day by pregnancy interaction. However, there was no effect ($P = .32$) of norgestomet on the secretion of progesterone by the corpus luteum nor were any treatment interactions significant ($P > .10$).

The reduction in progesterone concentrations during Syncro-Mate B treatment period in postpartum cows reported by Barnes et al., (1) may not have been caused by the norgestomet implant. Favero (5) found that the use of Syncro-Mate B (including both the injection and the norgestomet implant) on day 12 post-AI decreased pregnancy rates of beef heifers to almost 5 % while they obtained a 53 % pregnancy rate with the use of norgestomet implants alone for re-synchronization.

The administration of norgestomet during the mid-luteal phase had no effect on progesterone secretion by the corpus luteum for pregnant and non-pregnant heifers. Therefore, although norgestomet implants suppressed estrus, they had no effect on progesterone secretion by the corpus luteum of pregnant heifers and had no effect on the regression of the corpus luteum of non-pregnant heifers.

Experiment 2. During the Syncro-Mate B (SMB) estrus synchronization procedure, 28 of the 440 (6.4 %) initial number of heifers lost their implants and were consequently eliminated from the study as decided before initiation of the study. Prior to estrus synchronization, 67% (278 of 412) of the heifers were already exhibiting estrous cycles. The other 33% (134 of 412) were pre-pubertal or acyclic. The distribution of cyclic and prepubertal heifers was similar ($P > .25$) for all three groups.

Analysis of the progesterone and electrical resistance diagnosis of pregnancy are reported in table 1. For heifers in groups 2 and 3 that calved to the first AI and had progesterone concentrations of 1.5 ng/ml or greater, accuracy of electrical resistance diagnosis of pregnancy decreased as electrical resistance cut-off was increased. For heifers in groups 2 and 3 that calved to the second AI and had progesterone concentrations of less than 1.5 ng/ml, accuracy of electrical resistance diagnosis of pregnancy increased as electrical resistance cut-off was increased. For heifers in groups 2 and 3 that did not calve to the first two inseminations accuracy of electrical resistance diagnosis of pregnancy increased as the cut-off of increased. The accuracy of progesterone diagnosis of pregnancy status for the open heifers of

groups 2 and 3 was 75 %. Progesterone diagnosis of pregnancy and electrical resistance diagnosis of pregnancy agreed up to 86 % of the time. Previous data have demonstrated that the best cut-off for diagnosis of pregnancy with progesterone concentrations was 1.5 ng/ml (4). However, the ideal cut-off for diagnosis of pregnancy with electrical resistance is not clear.

Data for table 1 suggest similar results for a wide range of electrical resistance cut-offs. In order to identify the best cut-off, theoretical data were determined and are reported in table 2. There are two potential errors of inaccurate diagnosis. First, breeding pregnant heifers diagnosed non-pregnant (false negatives) causing abortion and second not breeding open heifers diagnosed pregnant (false positives). Based on the theoretical data in table 2 there is a relative wide range of efficacious cut-offs, however 80 and 81 would be the best electrical resistance cut-offs with the fewest losses of pregnancy. We used 81 in this study for breeding heifers in group 2.

The accuracy, sensitivity, specificity, positive predictive value, negative predictive value, false positives, and negative positives for progesterone and electrical resistance diagnosis of pregnancy are reported in table 3. Although, progesterone was numerically better for all factors, statistically ($P > .25$) they were equivalent in the diagnosis of pregnancy.

Pregnancy rates to the Syncro-Mate B timed artificial inseminations were based on calving data 283 ± 11 days from date of first artificial insemination. Pregnancy rates of the cyclic heifers (19%) were higher ($P < .05$) than for the acyclic heifers (8%). First service pregnancy rates were similar ($P > .25$) for the three treatment groups (table 4). The cause of the overall low pregnancy rates obtained in this study were unknown but may be because of one or a combination of the following factors. First, heifers used in the study had low body weight which might have delayed the age at puberty and decreased fertility of cyclic heifers. Secondly, the genetic origin of the heifers was unknown. Thirdly, the administration of growth stimulants to heifers (which was unknown for heifers in this study) has been shown to adversely affect their fertility. Fourthly, the inexperience of the inseminators to inseminate a large number of animals at once may have also affected the fertility of the heifers.

The ability of norgestomet implants to synchronize estrus and ovulation was analyzed from second service pregnancy rates at calving. Pregnancy rates of norgestomet re-synchronized heifers were based on calving data 283 ± 11 days from date of second artificial insemination as reported in table 4. Heifers in the control group had a higher ($P < .05$) pregnancy rates than heifers bred by electrical resistance diagnosis but similar ($P > .10$) pregnancy rates to heifers bred by progesterone diagnosis. Pregnancy rates for re-synchronized heifers (progesterone and electrical resistance diagnosis) were similar ($P > .10$). The combined (1st and 2nd service pregnancy rates) were similar to the results of the second AI because of the influence of the second AI data. Higher pregnancy rates to re-synchronization have been previously reported (4,5). The control heifers were not re-synchronized and were exposed to

fertile bulls beginning 12 days after the first AI. Therefore, it is not surprising that re-synchronized heifers had lower pregnancy rates. The effect of bull exposure may have had a beneficial affect on the control heifers. Further, control heifers that had short estrous cycles may have had a greater likelihood of becoming pregnant to a natural service than those re-synchronized.

Previous studies have demonstrated that electrical resistance is correlated to progesterone concentrations (9). However, little diagnostic value of a single reading has been found. In the re-synchronization program, at the time of implant removal and AI there is a wide divergence in progesterone concentrations as depicted in figure 1. Because of the wide divergence in progesterone concentrations, variation in the electrical resistance reading is reduced. Electrical resistance could have a potential diagnostic value for re-synchronization if devices are consistent 1) from herd to herd, 2) from year to year, and 3) within temperature variations.

In summary, these two studies demonstrate that norgestomet has no adverse affect on the progesterone secretion from the corpus luteum. Further, results from these studies demonstrate that electrical resistance can be used to identify non-pregnant heifers for re-breeding subsequent to re-synchronization nearly as efficaciously as progesterone determinations.

REFERENCES

1. Barnes, M.A., G.W. Kazmer, and S.T. Bierley. 1981. Gonadotropin and ovarian hormone responses in dairy cows treated with norgestomet and estradiol valerate. *Theriogenology* 16:13-25.
2. Brown, L.N., K.G. Odde, M.E. King, D.E. Leftover, and C.J. Neubauer. 1988. Comparison of MGA-PGF_{2α} to Syncro-Mate B for estrus synchronization in beef heifers. *Theriogenology* 30:1-12.
3. Cochran, William G. and Gertrude M. Cox. 1957. *Experimental Designs*. John Wiley & Sons., Inc., New York, pp. 577-582.
4. Favero, R.J. 1992. Methods of fertility enhancement and control of Beef females. Ph.D Thesis. University of Illinois at Urbana-Champaign, 151 pp.
5. Favero, R.J., D.B. Faulkner, and D.J. Kesler. 1993. Norgestomet implants synchronize estrus and enhance fertility in beef heifers subsequent to a timed artificial insemination. *J. Anim. Sci.* 71:2594-2600.
6. Fletcher, Robert H., Suzanne W. Fletcher, and Edward H. Wagner. 1988. *Clinical Epidemiology*. 2nd Ed., Williams and Wilkins, Baltimore, MD, pp. 42-75.

7. Hixon, D.L., D.J. Kesler, T.R. Troxel, D.L. Vincent, and B.S. Wiseman. 1981. Reproductive hormone secretions and first service conception rate subsequent to ovulation control with Syncro-Mate B. *Theriogenology* 16:219-229.
8. Kesler, D.J., H. Khazali, and R.J. Favero. 1990. Quantification of steroids via a polymer linked second antibody enzyme immunoassay: methods of linking anti-rabbit IgG to poly(styrene). In: *Progress in Biomedical Polymers*. Ed., C.G. Gebelein and R. Dunn, Plenum Publishing Co., NY. USA. pp. 157-170.
9. Leidel, W., and R. Strolla. 1976. Measurement of electrical resistance of the vaginal mucus as an aid for heat detection. *Theriogenology* 6:237-249.
10. Moseley, W.M., D.W. Forrest, C.C. Kaltenbach, and T.G. Dunn. 1979. Effect of norgestomet on peripheral levels of progesterone and estradiol-17 β in beef cows. *Theriogenology* 11:331-343.
11. Odde, K.J. 1990. A review of synchronization of estrus in postpartum cattle. *J. Anim. Sci.* 68:817-830.
12. SAS/STAT User's Guide. 1988. SAS Institute Inc., Cary, NC.
13. Wishart, D.F. 1972. Identification of steroids of high activity for control of oestrous cycle in the dairy heifers. *J. Reprod. Fertil.* 30:333-334.
14. Wiseman, B.S., D.L. Vincent, P.J. Thomford, N.S. Scheffrahn, G.S. Sargent, and D.J. Kesler. 1982. Changes in porcine, ovine, bovine and equine blood progesterone concentrations between collection and centrifugation. *Anim. Reprod. Sci.* 5:157-165.

Table 1. Percentage correct diagnosis of pregnancy status by progesterone diagnosis and by electrical resistance diagnosis and their agreement in pregnancy diagnosis.

	<u>Correct Diagnosis</u>			
	<u>Heifers Pregnant to</u>		Open Heifers ^c	Prog./ER Agreement ^d
	1st AI ^a	2nd AI ^b		
Progesterone ^f	-- ^e	-- ^e	75 %	
Electrical Resistance				
75 & +	94 %	85 %	67 %	82%
76 & +	94 %	88 %	79 %	83%
77 & +	94 %	91 %	71 %	84%
78 & +	92 %	93 %	71 %	85%
79 & +	92 %	95 %	73 %	86%
80 & +	92 %	98 %	73 %	86%
81 & +	92 %	98 %	74 %	86%
82 & +	86 %	98 %	74 %	86%
83 & +	83 %	100%	75 %	86%
84 & +	83 %	100%	76 %	86%
85 & +	83 %	100%	76 %	86%
86 & +	83 %	100%	78 %	85%

^a Heifers that calved to the first timed AI and had progesterone concentrations of 1.5 ng/ml or greater at 21 days after the first AI (the time of re-synchronization implant removal).

^b Heifers that calved to the second timed AI and had progesterone concentrations of less than 1.5 ng/ml at 21 days after the first AI (the time of re-synchronization implant removal).

^c Heifers that did not calve to the two timed AI's.

^d Agreement of progesterone concentrations (1.5 ng/ml and greater = pregnant and less than 1.5 ng/ml = non-pregnant) and electrical resistance (81 and greater = pregnant and less than 81 = non-pregnant) in assessing pregnancy status.

^e By definition both were 100 % accurate.

^f Heifers with progesterone concentrations of 1.5 ng/ml or greater were diagnosed pregnant.

Table 2. Theoretical^a missed pregnancies with electrical resistance readings by either breeding pregnant heifers or not breeding open heifers.

Electrical Resistance Readings	<u>Per 100 Pregnancies</u>		Percent per 100 heifers ^d
	Aborted ^b to 1st AI	Missed Pregnancies ^c to 2nd AI	
75 & +	1	8	5 %
76 & +	1	6	4 %
77 & +	1	5	3 %
78 & +	1	4	3 %
79 & +	1	3	3 %
80 & +	1	1	2 %
81 & +	1	1	2 %
82 & +	3	1	3 %
83 & +	3	0	3 %
84 & +	3	0	3 %
85 & +	3	0	3 %
86 & +	3	0	3 %

^a Based on a pregnancy rate of 50 % to a synchronized timed AI.

^b Based on a loss of 36 % of bred pregnant cows (Favero, 1992) and data from table 1 (for example 6 pregnant cows/100 bred X 50 % pregnancy rate X 36 % loss of bred pregnant cows = 1 aborted).

^c Based on a pregnancy rate of 50 % and data from table 1 (for example 6 pregnant cows/100 bred X 50 % pregnancy rate = 3 missed pregnancies).

^d Based on 100 heifers over the two AI period. For example, 100 heifers with a 50 % pregnancy rate for both AI's. Therefore, after the first AI, 50 would be pregnant. However, if bred by the electrical resistance reading of 75, one percent of the 50 would be lost. Further, for the remaining 50 open heifers 8 potential pregnancy per 100 would not be bred. Therefore, 5 pregnancies for the original 100 heifers would be missed.

Table 3. The accuracy, sensitivity, specificity, positive predictive value, and negative predictive value of progesterone and electrical resistance diagnosis of pregnancy of beef heifers re-synchronized with norgestomet implants.

Item	Electrical Resistance ^a	Progesterone ^b
Accuracy ^c	82 %	85 %
Sensitivity ^d	92 %	100 %
Specificity ^e	81 %	82 %
Positive Predictive Value ^f	45 %	49 %
Negative Predictive Value ^g	98 %	100 %
False Positives ^h	17 %	15 %
False Negatives ⁱ	1 %	0 %

^a Heifers were diagnosed pregnant if electrical resistance readings collected at 48 hours after removal of the re-synchronization implants (the timed second AI) were 81 or greater.

^b Heifers were diagnosed pregnant if progesterone values collected at re-synchronization implant removal were 1.5 ng/ml or greater.

^c Accuracy was equal to number pregnant with pregnant readings^j + number open with non-pregnant readings^k divided by the total number of heifers.

^d Sensitivity was equal to number pregnant with pregnant readings divided by the total number pregnant.

^e Specificity was equal to the number open with non-pregnant readings divided by the total number open.

^f Positive Predictive Value was equal to number pregnant with pregnant readings divided by the total number with pregnant readings.

^g Negative Predictive Value was equal to the number open with non-pregnant readings divided by the total number with non-pregnant readings.

^h False Positives are heifers with pregnant readings that are open.

ⁱ False Negatives are heifers with non-pregnant readings that are pregnant.

^j Pregnant readings were either progesterone values of 1.5 ng/ml or greater or electrical resistance readings of 81 or greater.

^k Non-pregnant readings were either progesterone values of less than 1.5 n/ml or electrical resistance readings of less than 81.

Table 4. Pregnancy rates to the first and second timed inseminations of beef heifers bred after re-synchronization by electrical resistance and progesterone diagnosis.

Group	n	<u>Insemination</u>		Combined
		1 st	2 nd	
Control ^c	135	22 (16%) ^a	49 (36%) ^a	71 (53%) ^a
Electrical Resistance ^d	122	17 (14%) ^a	27 (22%) ^b	44 (36%) ^b
Progesterone ^e	155	26 (18%) ^a	39 (25%) ^{a,b}	65 (42%) ^{a,b}

^{a,b} Columns with different superscripts differ ($P < .05$).

^c Bulls were included in the pasture with the control heifers beginning 12 days after the first AI and onwards.

^d Heifers with electrical resistance readings of less than 81 (collected immediately before AI) were bred via AI 48 hours after removal of the re-synchronization implant.

^e Heifers with progesterone concentrations of less than 1.5 ng/ml (collected at the time of re-synchronization implant removal) were bred via AI 48 hours after removal of the re-synchronization implant.

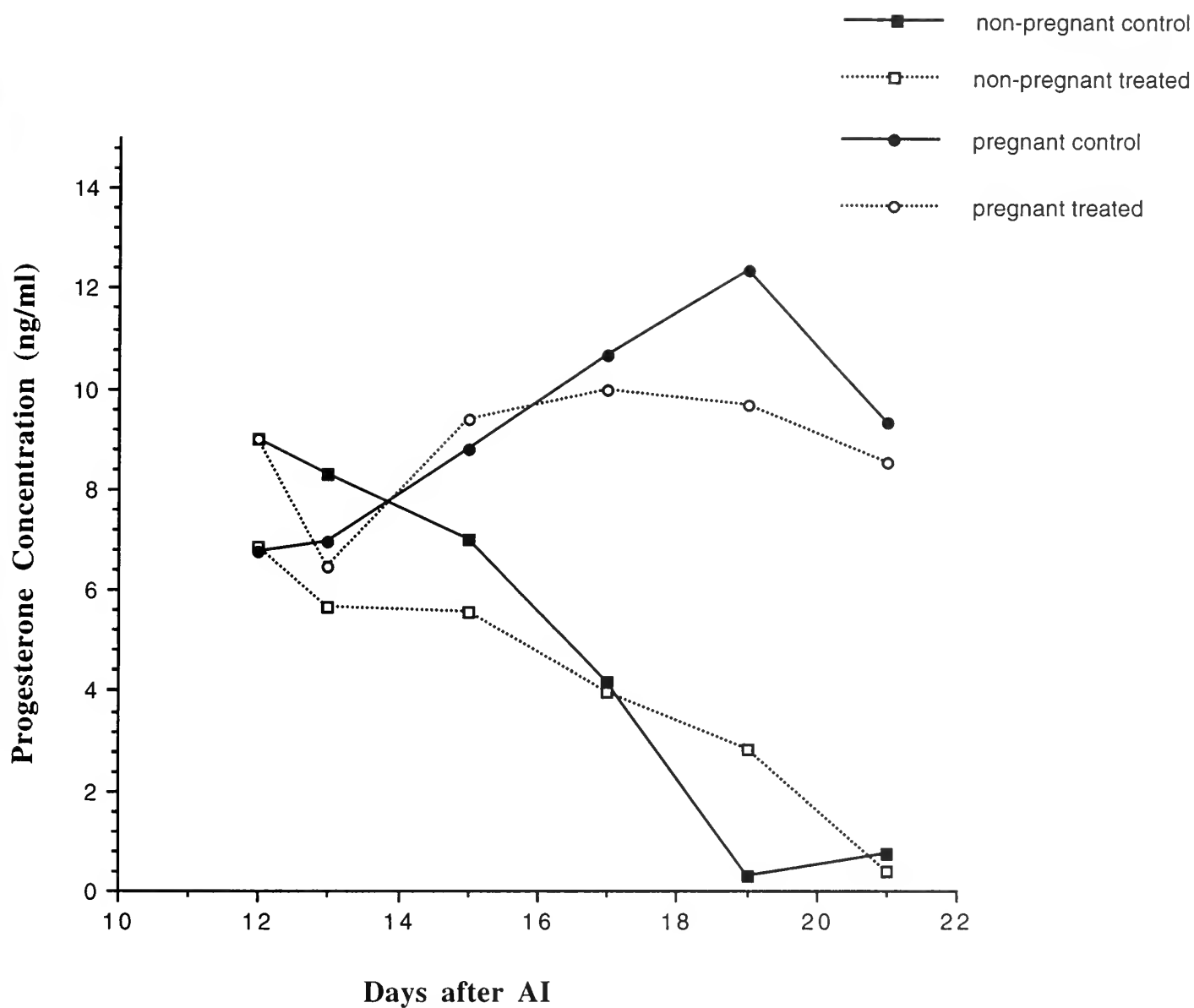


Figure 1. Progesterone concentrations (ng/ml) of untreated and morganstomet-treated pregnant and non-pregnant heifers. Implantation was done on day 12 and implants were left in situ for 9 days.

A COMPARISON OF HYDRON AND SILICONE IMPLANTS IN THE NORGESTOMET AND ESTRADIOL VALERATE ESTRUS SYNCHRONIZATION PROCEDURE

D.J. Kesler, R.J. Favero, and T.R. Troxel

SUMMARY

Hydron and silicone implants impregnated with norgestomet were used in the bovine norgestomet and estradiol valerate estrus synchronization procedure. Efficacy data demonstrated that synchronized pregnancy rates were greater (44 % vs 53 %; $P < .01$) for cattle treated with the procedure utilizing the silicone implant.

INTRODUCTION

Although pregnancy results are sometimes variable (Favero et al., 1988; Odde, 1990) after Syncro-Mate B® synchronization, cattle responding exhibit estrus at such a uniform time that timed insemination can be utilized. The commercial procedure utilizes a matrix implant composed of norgestomet impregnated in poly(ethylene glycomethacrylate) (hydron) (Chien, 1978). Poly(dimethylsiloxane) (silicone) has also be successfully utilized to delivery steroids in a controlled fashion (Favero et al., 1990; Favero et al., 1993).

The purpose of these studies was to evaluate the alternative silicone implant impregnated with norgestomet in the norgestomet and estradiol valerate estrus synchronization procedure.

PROCEDURES

Efficacy was determined in 260 beef cows and heifers at five locations. Cattle at locations 1 and 3 were beef heifers while cattle at locations 2, 4, and 5 were postpartum beef cows. Day zero was the day that implants were inserted and injections administered. On day nine implants were removed. Approximately 48 hours after implant removal cattle were artificially inseminated with semen from fertile bulls without regard to estrus. Pregnancy was determined nine months later during the calving season (pregnancy rate = number calving to the synchronized insemination \div total number treated).

Data were analyzed by analysis of variance as described by Chinchilli (1988).

RESULTS

Pregnancy rates determined in 260 beef heifers and cows demonstrated that utilization of the silicone implant with the norgestomet and estradiol valerate estrus synchronization was more efficacious ($P < .01$) than utilization of the hydron implant (table 1). Pregnancy rates were 19 % higher when silicone implants were utilized in the estrus synchronization procedure. Results were consistently higher (ranging from 10 % to 64 % improvement) for the silicone implanted animals at all locations. The location effect and the location by treatment interaction were non-significant ($P > .25$).

Table 1. Pregnancy rates subsequent to a timed insemination after a hydron implant and silicone implant norgestomet and estradiol valerate estrus synchronization procedure^a.

Location	Hydron	Silicone
1. Heifers	10/ 28 (36 %)	13/ 30 (43 %)
2. Postpartum Cows	15/ 34 (44 %)	17/ 35 (49 %)
3. Heifers	4/ 12 (33 %)	6/ 11 (55 %)
4. Postpartum Cows	6/ 14 (43 %)	6/ 11 (55 %)
5. Postpartum Cows	23/ 43 (53 %)	26/ 42 (62 %)
Combined	58/131 (44 %)	68/129 (53 %)

^a The norgestomet and estradiol valerate estrus synchronization procedure consists of the implantation of a 6 mg norgestomet impregnated implant and the injection of 3 mg of norgestomet and 5 mg of estradiol valerate on day 0. On day 9 implants are removed and cattle are bred either by estrus detection or by timed breeding 48 to 52 hours after implant removal.

CONCLUSION

In summary, it is recommended that the 6 mg norgestomet/silicone implant be used to deliver norgestomet in vivo in the norgestomet and estradiol valerate estrus synchronization program in cattle. Subsequent fertility, the goal of the program, was improved when the silicone implant was utilized.

REFERENCES

- Chien, Y.E. Methods to achieve sustained drug delivery. A physical approach: implants. In: Sustained and Controlled Release Drug Delivery Systems (J.R. Robinson, ed.), Marcel Dekker, Inc., NY (1978).
- Chinchilli, V.M. Clinical efficacy trials with quantitative data. In: Biopharmaceutical Statistics for Drug Development (K.E. Peace, ed.), Marcel Dekker, Inc., NY (1988).
- Favero, R.J., D.B. Faulkner, and D.J. Kesler. Estrous synchronization in beef females with Syncro-Mate B: efficacy and factors that restrict optimal pregnancy rates. *Theriogenology* 29:245 (1988).
- Favero, R.J., D.B. Faulkner, and D.J. Kesler. Norgestomet implants synchronize estrus and enhance fertility in beef heifers subsequent to a timed artificial insemination. *J. Anim. Sci.* 71:2594-2600 (1993).
- Favero, R.J., E.A. Henderson, and D.J. Kesler. The ability of norgestomet impregnated poly(dimethylsiloxane) implants to maintain pregnancy subsequent to ovariectomy. *Progress in Biomedical Polymers* (C.G. Gebelein and R.L. Dunn, eds.), Plenum Press, NY, pp. 355-361 (1990).
- Odde, K.G. A review of synchronization of estrus in postpartum cattle. *J. Anim. Sci.* 68:817-830.

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WHOLE SERA PROGESTERONE ELISA

T.L. Steckler and D.J. Kesler

SUMMARY

A sensitive whole sera progesterone ELISA was developed and validated to quantitatively determine progesterone concentrations in bovine blood. This assay requires only 2 hours after sera collection and can be used to clinically determine pregnancy status or cyclicity status, or determine progesterone concentrations for research purposes in cattle.

INTRODUCTION

ELISA's (enzyme linked immunoabsorbent assays) are used for both basic and applied research. The ELISA progesterone is used to quantitatively determine progesterone concentrations in blood sera or plasma. The procedure is extremely sensitive and specific (Kesler et al., 1990). The ELISA is a modification of the RIA (radioimmunoassay; Yalow, 1978). Rather than utilization of a radioisotope, an enzyme is used. This makes the procedure safer and its use can be widespread since the governmental control on radioisotopes is removed. However, the progesterone in the sera and plasma must be extracted. This involves organic solvents (petroleum ether) which also contribute potential problems to not only the environment but to the technician.

In addition, the current ELISA uses a polyclonal antibody (Kesler, 1993). Polyclonal antibodies, although very efficacious, are limited in quantity since they are harvested from rabbit sera and change not only between rabbits but across time within a rabbit. Today, numerous monoclonal antibodies are available. Monoclonal antibodies are of greater value since they are produced from modified spleen cells that can be stored indefinitely (Tijssen, 1985). Therefore, there is no limit on the quantity of monoclonal antibody that can be produced.

The progesterone ELISA has more than just research applications. It is also used to clinically to determine pregnancy. This can significantly improve management of cattle operations.

The objective of this experiment was to develop a progesterone ELISA that utilizes a monoclonal antibody and unmanipulated sera.

PROCEDURES

Primary monoclonal antibodies (antibodies to progesterone) were selected and purchased from reputable vendors. These antibodies were then tested in the current ELISA (Kesler et al., 1990) for binding to the secondary antibody (anti-rabbit IgG). The primary monoclonal antibodies were then linked to the solid support (polystyrene microtiter plates). After selection of the best monoclonal antibody, the proper dilution and the most efficient procedure were determined and then sensitivity and accuracy of the assay were determined.

RESULTS AND DISCUSSION

The binding of the primary monoclonal antibody to anti-rabbit IgG coated plates was determined first. To determine binding, conjugate and various dilutions of primary monoclonal antibody were added to a anti-rabbit IgG coated plate. After 1.5 hours of incubation the liquid was washed off. After 30 minutes of incubation with 3,3',5,5' tetramethylbenzidine (TMB) substrate the plate was read at 630 nm. Of all dilutions tested the maximum binding was 18 % of the binding obtained with the polyclonal antibody. The use of established anti-rabbit IgG coated plates was therefore rejected for possible use in the whole sera assay.

Various dilutions of the primary antibody were then linked to the polystyrene plates. After determining the optimum dilution for linking the monoclonal antibody to the plate the most efficient assay procedure was determined.

The basic assay developed consists of the following.

- 1) Monoclonal progesterone antibody (OEM Concepts, Inc.) linked to polystyrene microtiter plates (1:12,500).
- 2) Progesterone conjugate (1:125,000) as used in the extracted progesterone assay. The final volume per well is 100 μ L.
- 3) Progesterone standards were 1/2 of the standard concentrations used in the extracted progesterone assay. The final concentration per well is 0, .125 ng, .75 ng, 2.0 ng, and 5 ng all in 50 μ L of PBS-gel. Standards also have 50 μ L of sera from estrus/dexamethasone treated cows added at least 24 hours before assay time. These may be stored at -20°C.
- 4) At assay time, 500 μ L of conjugate and 500 μ L of standard are added to 12 X 75 disposable culture tubes and vortexed. For unknown samples, 500 μ L of conjugate, 250 μ L of unknown sera, and 250 μ L of PBS-gel are added to 12 X 75 culture tubes and mixed. These tubes are then placed in a rack for use with a multichannel pipetter.
- 5) With a multichannel pipetter, the conjugate/sera/PBS-gel mixture is added to the microtiter plate with dispatch.
- 6) Plates are incubated for 1.5 hours.

- 7) Wells are then washed with distilled water 3 times each.
- 8) After removal of all excess water, 200 μ L of TMB substrate is added to each well.
- 9) TMB is incubated for 25 minutes static and then 5 minutes on the vortex (at low speed).
- 10) Plates are read on a microtiter plate reader at a wavelength of 630 or 655 nm. Microtiter plate reader should be able to read the entire plate within 10 seconds.

Preliminary validation was conducted with the assay. Results are reported in table 1.

Table 1. Sensitivity and Accuracy of the Whole Sera Progesterone ELISA.

Standard Concentration	Binding	Predicted Concentration
0	100 %	0
125 pg	81 %	127 pg
750 pg	59 %	713 pg
2,000 pg	46 %	1,956 pg
5,000 pg	34 %	5,460 pg
r (logit/log):		.999
Accuracy:		96.45 %
Sensitivity:		50.00 pg
r (with extracted assay)		.996

Progesterone assays have successfully been used to determine pregnancy status of cows 21 days after breeding. This diagnostic test has been very valuable particularly when cows are re-synchronized with norgestomet and it is imperative to know which cow are not pregnant and need to be inseminated (Favero et al., 1993). When progesterone concentrations are low, the diagnosis of open is almost always (> 99 %) correct. When progesterone concentrations are high (equal to or greater than 1.5 ng/ml) the diagnosis of pregnant is 85 to 90 % accurate.

CONCLUSION

A whole sera progesterone ELISA was developed utilizing monoclonal anti-progesterone. This allowed quantification in a shorter period of time since progesterone extraction is no longer required. In addition, the assay is safer because of the elimination of petroleum ether which is used for extraction. Utilization of

monoclonal anti-progesterone guarantees that the assay can be performed indefinitely.

REFERENCES

- Favero, R.J., D.B. Faulkner, and D.J. Kesler. 1993. Norgestomet implants synchronize estrus and enhance fertility in beef heifers subsequent to a timed artificial insemination. *J. Anim. Sci.* 71:2594-2600.
- Kesler, D.J., H. Khazali, and R.J. Favero. 1990. Quantification of steroids via a polymer linked second antibody enzyme immunoassay system: methods of linking anti-rabbit IgG to polystyrene. In: *Progress in Biomedical Polymers*, Plenum Press, NY, p. 157-170.
- Kesler, D.J. 1993. Lyophilized immunoassay reagents and blood samples. *Am. Biotechnology Laboratory* 11:34-36.
- Tijssen, P. 1985. *Practice and Theory of Enzyme Immunoassays*. Elsevier, Amsterdam.
- Yalow, R.S. 1978. Radioimmunoassay: a probe for the fine structure of biologic systems. *Science* 200:1236-1245.

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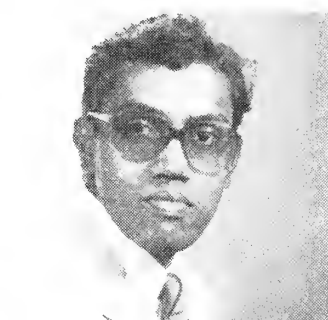
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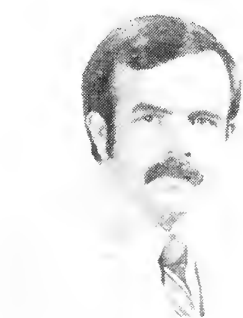
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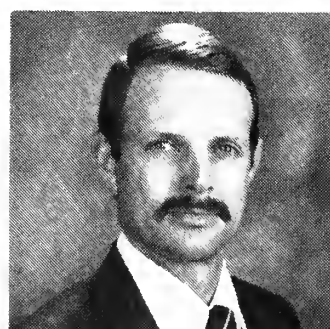
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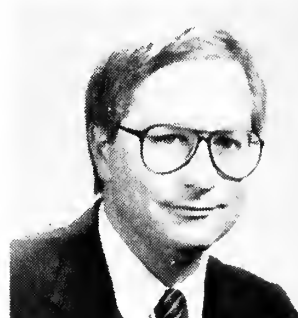
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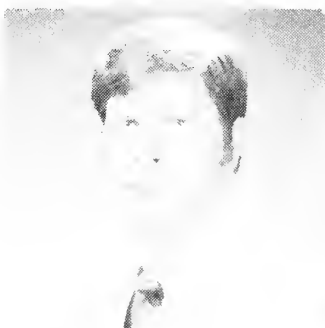
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THE DEPARTMENT OF ANIMAL SCIENCES
University of Illinois

Robert A. Easter, Head of Department

The beef report results from the efforts of faculty, graduate students and the professional and non-academic support staff assigned to the Department of Animal Sciences. In summary, a significant investment is made annually by the citizens of Illinois in this research enterprise. The projects described in this publication represent only a selected portion of the total effort. Other, often more basic investigations are described in articles published each year in various academic journals and the proceedings of national and international conferences on beef cattle science. We are proud of the accomplishments of these scientists and hope that you will find the information provided here to be useful.

With a research herd totaling almost 1,000 beef cows and feedlot operations at the campus, Dixon Springs and Orr Agricultural Centers, the Department is very sensitive to the economic forces that impact Illinois producers. Ultimately, the income generated from the sale of animals has to pay much of the expense associated with maintaining our research herds. A logical consequence is the need to understand the factors that influence both production efficiency and market value of the finished animal. During the past year we have given significant attention to understanding market requirements. The approach has been through a research and demonstration project known on this campus as Beef-2000.

Beef-2000 is an on-going effort supported by the grants from the Council for Agricultural Research (C-FAR), the Illinois Beef Association and the Illinois Agricultural Experiment Station. The approach is straight-forward. Representative genotypes of varying beef market animals are obtained and fed in the feedlot on our Urbana campus. Four groups of 25 producers each have been invited to campus to participate in the final live and carcass evaluation. Retail cuts were fabricated and the actual value of marketable product resulting from each genotype was determined. The Beef-2000 project will continue during 1997 with the next group of cattle scheduled for slaughter in June.

We, like many others, are seeking to understand the impact that changing communication technologies will have on our lives. Because one of the National Centers for Supercomputer Applications is located on the Urbana campus of the University of Illinois, we are well-positioned to take advantage of emerging technologies. For example, the catalogue for the 29th annual bull sale can be found on our Livestock Systems Home page at: <http://w3.aces.uiuc.edu/Aim/Auction>. You will also find a copy of this beef report on that home page as well as a number of other items of interest.

Finally, we continue to appreciate the support of the Illinois beef industry and the excellent cooperation enjoyed with the Illinois Beef Association. Best wishes for the year ahead.

METHODS OF IMPROVING PERFORMANCE OF BEEF CATTLE GRAZING TALL FESCUE PASTURES

F. A. Ireland, D. B. Faulkner, T. D. Saxe, and E. L. Piper

INTRODUCTION

Even with the adverse clinical signs associated with livestock grazing tall fescue (*Festuca arundinacea*) pastures infected with the endophytic fungus, *Acremonium coenophialum* (Morgan-Jones and Gams, 1982), tall fescue remains one of the most abundant forage crops in the United States (Jackson *et al.*, 1984). It occupies more than 14 million ha (Buckner *et al.*, 1979) and is the most widely utilized cool-season perennial grass in the southeast (Steen *et al.*, 1979; Pendulum *et al.*, 1980). In a survey of 21 states, an estimated 8.5 million cattle graze tall fescue pastures (Hoveland, 1993). Tall fescue continues to be extensively utilized because it has a wide range of adaptation and is easily established as a forage species. The endophyte of tall fescue may also contribute to the hardiness of the plant by increasing the plants tolerance to drought conditions (West *et al.*, 1987) may increase resistance to insects (Johnson *et al.*, 1985; Latch *et al.*, 1985; Yates *et al.*, 1989), and may confer pathogen resistance to the plant (White, Jr. and Cole, 1985). In addition, it provides an extended grazing season and is tolerant to poor management practices (Stuedemann and Hoveland, 1988).

Animal performance has been reported to be reduced below expected levels when consuming tall fescue (Pratt and Haynes, 1954). Paterson, *et al.* (1995) reported that the major animal conditions associated with the consumption of endophyte-infected tall fescue were fescue foot, fat necrosis, agalactia, and fescue toxicosis. The symptoms of the fescue toxicosis syndrome include reduced body weight gains and feed intake in cattle (Schmidt *et al.*, 1982; Hoveland *et al.*, 1983; Boling, 1985) and horses (Redmond *et al.*, 1991), rough hair coat, reduced blood flow to the periphery resulting in an increase in body temperature (Carr and Jacobson, 1969; Walls and Jacobson, 1970; Rhodes *et al.*, 1991), fescue foot (Cunningham, 1949; Goodman, 1952; Ashley, 1958), reduced reproductive performance in cattle (Beers and Piper, 1987; Gay *et al.*, 1988; Essig *et al.*, 1989) lower milk production (Stidham *et al.*, 1982; Daniels *et al.*, 1984; Danilson *et al.*, 1986) and lower serum prolactin concentrations (Porter *et al.*, 1985; Bond and Bolt, 1986; Elasser and Bolt, 1987).

The economic impact on the beef cattle industry in the United States has been estimated at an annual loss of over \$600 million (Hoveland, 1993). With endophyte-infected tall fescues reported in Poland, France, Italy, Wales, and New Zealand (Latch *et al.*, 1984; Siegel *et al.*, 1984), the problem is not limited to the United States, but becomes a global problem.

Because the endophyte fungus is concentrated in the seedhead, grazing management to reduce stem and seedhead formation has shown some potential for improving animal performance (Bransby *et al.*, 1988). The use of a plant growth regulator to retard seedhead formation has also resulted in increased weight gain in steers grazing endophyte-infected tall fescue pastures (Turner *et al.*, 1990).

Another method of diluting the amount of endophyte-infected forage consumed, while maintaining a desired level of animal performance, has been the practice of supplementation with grain and grain by-products. However, in one study, forage OM intake was decreased when steers were supplemented (1% BW) with either corn or corn gluten feed. Corn decreased forage OM digestibility, but corn gluten feed did not (Hannah *et al.*, 1989). It has been suggested that reduced forage intake of cattle grazing endophyte-infected pastures could partially account for the reduction in animal performance. Peters *et al.* (1992) reported that OM intake was lower for cows on infected pastures than non-infected when environmental temperatures were higher in August, but were similar during cooler temperatures in June. However, cows that grazed endophyte-infected pastures lost weight as compared to cows grazing low endophyte pastures even during the grazing period when OM intakes were similar. This is in agreement with Aldrich *et al.* (1993) and Forcherio *et al.* (1993), but conflicts with Forcherio *et al.* (1992) where OM intake was greater for cows grazing low endophyte pastures from May to July. In addition to differences in OM intake, digestibility may be altered with high endophyte diets (Hannah *et al.*, 1990; Aldrich *et al.*, 1993).

One of the most consistent observations in animals consuming endophyte-infected tall fescue is a decreased serum prolactin concentration (Porter *et al.*, 1985; Bond and Bolt, 1986; Elsasser and Bolt, 1987). The reduction in prolactin secretion is most likely caused by compounds, such as ergot alkaloids and ergopeptines, found in endophyte-infected tall fescue which interact with dopamine receptors (Strickland *et al.*, 1993).

It has been recently reported that treatment with the commercially available anthelmintic, ivermectin, has produced weight gain in steers grazing infected tall fescue above the level that would be expected from benefits derived from deworming (Bransby *et al.*, 1992). Ivermectin is utilized extensively in livestock production as an effective wormer (Entrocasso *et al.*, 1996). It has been shown to lower fecal egg counts, hasten the onset of puberty and improve pregnancy rates in cattle (Larson *et al.*, 1995). Crawford, Jr., *et al.* (1990) indicated that ivermectin had the potential to produce a slight reduction in heat stress and improvement in weight gain in steers. Crawford, Jr., and Garner (1991) reported that with steers initially treated with zeranol and ivermectin, reducing the amount of tall fescue consumed by supplementation with corn gluten feed resulted in an increase in ADG. Furthermore, bi-weekly administration of ivermectin resulted in an additive increase in gain across all corn gluten feed levels.

Because the research indicates that ivermectin may have potential as a method for reducing fescue toxicosis and the fact that little data is available on the effects of ivermectin on serum prolactin concentrations, a series of studies were designed to evaluate the potential for ivermectin to increase weight gains above that expected from parasite control in cattle grazing endophyte infected tall fescue. The effects of ivermectin on serum prolactin concentrations, milk production, hair coat, rectal temperature, BCS, and calf performance were also evaluated.

MATERIALS AND METHODS

Trial 1. Sixty-four crossbred yearling heifers were randomly assigned to one of four treatments to evaluate the effects of a subcutaneous injection of ivermectin (IVO; Ivomec[®], MSD-AgVet-

Merck; 1 ml/45.3 kg BW) on body weight change, rectal temperature, body condition score (BCS), serum prolactin concentrations and hair coat scores while grazing high and low endophyte infected tall fescue (*Festuca arundinacea* Shreb.) pastures at the Dixon Springs Agricultural Center, Dixon Springs, IL. Angus crossbred heifers (average weight 275 kg) were randomly assigned to graze either high endophyte infected tall fescue cv. Kentucky-31(HE) or low endophyte tall fescue cv. Johnstone (LE) pastures at a stocking rate of 3.7 hd/ha. All heifers were treated orally with ten percent fenbendazole (Safe-Guard®, Hoechst-Roussel; 5 mg/kg BW) on d -7. One-half of each group received a subcutaneous injection of ivermectin (1 ml/45.3 kg BW) on July 18, 1994 (d 0). Full body weights, body condition scores (BCS) and hair coat scores were taken on d 0 and d 2 and averaged for on study values and again on d 28 and d 58. Body conditions were scored using a 1-9 scale, with a score of 1 representing an emaciated condition and a score of 9 an extremely fat condition (Richards *et al.*, 1986). Hair coats were scored on a 1-5 scale with a score of 1 representing a slick, shiny hair coat and a score of 5 indicating a very heavy, dull hair coat. Heifers were artificially inseminated on April 18, 1994 and exposed to bulls for breeding from April 14 to June 10, 1994. Pregnancy status was then determined by rectal palpation on d 64 following treatment with ivermectin. Rectal temperatures were taken using a digital thermometer on d 0, d 2, d 42, and d 58. Fecal samples were collected and parasite eggs/g of fecal material estimated on d -7, d 0, and d 58, using a modification of a technique described by Sheather (1923). A suspension was made containing 2 g of fecal material and 28 ml of water. One ml of Sheather's solution was added to 1 ml of the fecal suspension and mixed. A sample was then placed on a hemocytometer and worm eggs counted. Eggs/g of fecal material were estimated by taking the number of eggs in two full squares and multiplying by 150. Blood samples were collected by jugular venipuncture at 0800 hr and 1300 hr on d 0, and on d 2, d 9, d 18, d 28, d 42, and d 58 at 1300 hr, and immediately placed in crushed ice to prevent hormone metabolism (Wiseman *et al.*, 1982). Serum was separated by centrifugation at 1,000 x g, decanted, separated into two duplicate samples and stored at -20° C until analyzed for serum prolactin concentrations (Henson *et al.*, 1987). Forage samples were collected on d 9, lyophilized, ground and analyzed for ergovaline concentrations (Moubarak *et al.*, 1993). Data was analyzed using analysis of variance T test (LSD).

Trial 2. One-hundred-twenty yearling Angus-hereford crossbred steers (average weight 277 kg) were randomly assigned to one of five treatments of a replicated study to evaluate methods of increasing weight gains while grazing tall fescue (*Festuca arundinacea* Shreb.) pastures. Six steers were randomly assigned to one of twenty 2.02 ha pastures, resulting in four replicates of five treatments. On July 7, 1995 (d -4), steers were treated orally with fenbendazole (Safe-Guard®, Hoechst-Roussel; 5 mg/kg BW) and fecal egg counts taken on July 11, 1995 (d 0) to determine the level of parasite infestation. Steers were allowed to graze endophyte-infected tall fescue cv. Kentucky 31 for the following treatments: Trt 1, 0.9 kg/(hd·day) corn gluten feed; Trt 2, (Ralgro® zeranol) (Pitman-Moore) implant + 0.9 kg/(hd·day) corn gluten feed; Trt 3, zeranol implant; Trt 4, control. Treatment 5 consisted of steers grazing low-endophyte tall fescue cv. Johnstone. All pastures were fertilized in June of 1995 with ammonium nitrate at a rate of 56 kg actual nitrogen/ha and were stocked at 2.96 hd/ha for the trial. One-half of each group of six animals received a single subcutaneous injection of ivermectin (IVO) (Ivomec®, MSD-AgVet-Merck; 1 ml/45.3 kg BW) on d 0. Steers in Trt 2 and 3 received a single subcutaneous zeranol ear implant on d 0. Average daily gain (ADG) was calculated using body weights taken after 16

hr withdrawal from feed and water on d 0, d 35, and d 63. Blood samples were taken on d 0, d 35, and d 63 by jugular venipuncture and immediately placed in crushed ice. Serum was collected by centrifugation at 1,000 x g and stored at -20° C until assayed for prolactin concentrations (PRL1, PRL2, and PRL3). Fecal samples were collected from a subsample (n=20) of steers on each treatment on d 0 and from the same steers again on d 63 and parasite egg counts determined by the previously described procedure. Forage dry matter availability was estimated using a double sampling technique for forage density measurements using a rising plate meter (Bransby *et al.*, 1977) and calculated using the stepwise regression procedure of SAS (1985). Dry matter samples were collected for determination of ergovaline concentrations on d 9, d 45, and d 64. Data was analyzed by analysis of variance for a randomized design using the GLM procedures of SAS (1985). The use of animal as the experimental unit showed no interactions therefore, pasture was used in the analyses as the experimental unit. The model statement included ADG, PRL1, PRL2, PRL3, IVO, and their interactions as independent variables.

Trial 3. The objective of trial 3 was to evaluate the effect of ivermectin on milk production, serum prolactin concentrations, conception rate, cow weight gain, cow body condition score (BCS), calf weight gain and calf hip height for cow-calf pairs grazing endophyte infected tall fescue pastures. Seventy-seven crossbred cows received oral fenbendazole (Safe-Guard®, Hoechst-Roussel; 5 mg/kg BW) on July 7, 1995 (d -5) and were randomly assigned to one of two treatments. Cows on treatment 1 received a subcutaneous injection of ivermectin (Ivomec®, MSD-AgVet-Merck; 1 ml/45.3 kg BW) on d 0. Cows on treatment 2 received an injection containing an equivalent volume of normal saline. Calves received an oral dose of fenbendazole (5 mg/kg BW) on d -5. On d 0, one-half of the calves in each of the two cow treatment groups were given a subcutaneous injection (1 ml/45.3 kg BW) consisting of either ivermectin or a saline control. Cow body weights, BCS and calf hip heights were taken on d 0, d 1, d 35, d 70 and d 71. Calf weights were taken to the nearest .09 kg with an electronic scale (Mettler-Toledo Model 2158, System Scale, Indianapolis, IN) on d 1, d 35 and d 71 and milk production estimated following a weigh-suckle-weigh procedure as described by Buskirk *et al.*, (1995) on d 1 and d 35. Blood samples were taken by jugular venipuncture on d 0, d 35 and d 71 and immediately placed on crushed ice. Serum samples were collected by centrifugation at 1,000 x g, decanted, separated into two samples and stored at -20° C until assayed for prolactin concentrations (Henson *et al.*, 1987). Fecal samples were collected on d 0, d 35 and d 71 and evaluated for worm eggs/g of fecal material, as outlined above. Data was analyzed, using animal as the experimental unit, by analysis of variance for a randomized design using the GLM procedures of SAS (1985). The model statement included changes in calf hip height, changes in calf body weight, calf ADG, changes in milk production, where d 1 samples were used as a baseline to evaluate changes at d 35, changes in cow weight and cow BCS, beginning and ending pregnancy status and prolactin concentrations at d 0, d 35, and d 71.

RESULTS AND DISCUSSION

Trial 1. Heifers were assigned to one of two pasture groups, low endophyte (LE) or high endophyte (HE), and one half of each group was given a subcutaneous injection (1 ml/45.3 kg BW) of ivermectin immediately following the 0800 hr blood collection on d 0. Forage samples were taken on d 9 and a composite sample analyzed for ergovaline concentrations as an estimation

of ergot alkaloid concentration present in the pastures. Concentrations were 232 ppb and 11 ppb for high and low endophyte pastures, respectively.

Data for trial 1 are given in Table 1. Rectal temperatures were higher ($P < .05$) on d 42 for cattle grazing high endophyte pastures as compared to cattle grazing low endophyte pastures. This is in agreement with Carr and Jacobson (1969) and Rhodes *et al.* (1991) who measured changes in body temperature due to endophyte fescue. When measured on d 59, rectal temperatures were lower for the LE group than HE, high endophyte with ivermectin (HEI) or LEI. Mean rectal temperatures increased from d 0 to d 58 for all groups; however, the increase was less ($P < .05$) for LE than LEI, HE, or HEI groups. Environmental weather data are presented in Table 2. The data are in agreement with Peters *et al.* (1992) who reported that environmental temperatures play an important role in fescue toxicosis.

Blood samples were collected and serum analyzed for prolactin concentrations before and following treatment with ivermectin. As measured at 3 hr on d 0 and d 2, there was no effect on serum prolactin concentration due to treatment. By d 9, heifers grazing high endophyte pastures had lower serum prolactin concentrations than the LE group ($P < .01$). Heifers grazing low endophyte pastures had numerically higher serum prolactin concentrations on d 18 than high endophyte groups. There was also a slight numerical increase due to treatment with ivermectin. Serum prolactin concentrations were higher ($P < .01$) for LEI heifers as compared to HE and HEI groups. This increase was measured on d 28, with the LEI group having higher ($P < .01$) serum prolactin concentrations compared to HE heifers. By d 42, serum prolactin concentrations were not different due to treatment.

Trial 2. While there was a numerical increase in ADG by ivermectin treatment, statistically there was no difference ($P > .3$) and ivermectin was removed from the model. Average daily gain (ADG) was different between treatments ($P < .035$), with all treatments being different from Treatment 4 (Table 4). Treatments 1, 2, and 3 improved ADG above the high endophyte control (Trt 4) and were equal to the ADG of steers on low endophyte pastures (Trt 5).

Serum prolactin concentrations were higher ($P < .01$) on d 35 and d 63 in the low endophyte control group (Trt 5) than with treatments 1, 2, 3 and 4. Serum prolactin concentrations were not positively correlated with changes in ADG.

Using the regression equation $y = -1040.14 + 565.67x + -12.04x^2$, where y = DM yield of forage (kg/ha) and x = density of forage in cm, as measured by the rising plate meter, the range of available forage dry matter during the trial was 2934 to 5291 kg/ha. Mean weather data for the trial period are presented in Table 5.

There was no significant parasite infestation at the beginning of the trial and no significant reinfestation occurred during the trial period. On d 63, a fecal sample from one steer on Trt 2 had an estimated 300 moniezia benedeni eggs/g of fecal material. No other parasite eggs were observed in any other fecal samples taken on d 0 or d 63.

Trial 3. The numerical increase due to cow trt with ivermectin in cow BCS, cow weight gain, and calf weight gain was not different ($P > .05$), however, the decrease in milk production from d 0 to d 34 was reduced ($P < 0.03$) for cows receiving ivermectin, as compared to controls.

REFERENCES

- Aldrich, C. G., J. A. Paterson, J. L. Tate, and M. S. Kerley. 1993. The effects of endophyte-infected tall fescue consumption on diet utilization and thermal regulation in cattle. *J. Anim. Sci.* 71:164.
- Ashley, G. 1958. Fescue poisoning of cattle of Florida muck land. *JAVMA* 132:493.
- Beers, K. W. and E. L. Piper. 1987. Effect of grazing endophyte-infected fescue on heifer growth, calving rate and calf birth weight of first calf heifers. *Ark. Farm Res.* 36(5):2.
- Ben-David, M., A. Danon, and F. G. Sulman. 1970. Acute changes in blood and pituitary prolactin after a single injection of perphenazine. *Neuroendocrinology* 6:336.
- Ben-David, M., S. Dikstein, and F. G. Sulman. 1965. Production of lactation by non-sedative phenothiazine derivatives. *Proc. Soc. Exp. Biol. Med.* 118:265.
- Bernard, J. K., A. B. Chestnut, B. H. Erickson, and F. M. Kelly. 1993. Effects of prepartum consumption of endophyte-infested tall fescue on serum prolactin and subsequent milk production of Holstein cows. *J. Dairy Sci.* 76(7):1928.
- Boling, J. A., L. D. Bunting, G. M. Davenport, J. L. Van der Veem, K. M. Maekins, N. W. Bradley, and R. E. Kohls. 1989. Physiological responses of cattle consuming tall fescue to environmental temperature and supplemental phenothiazine. *J. Anim. Sci.* 67:2377.
- Bond, J. and D. J. Bolt. 1986. Growth, plasma prolactin and ovarian activity in heifers grazing fungus-infected tall fescue. *Nutr. Rep. Int.* 34:93.
- Bransby, D. I., A. G. Matches, and G. F. Krause. 1977. Disk meter for rapid estimation of herbage yield in grazing trials. *Agron. J.* 69:393.
- Bransby, D. I., S. P. Schmidt, W. Griffey, and J. T. Eason. 1988. Heavy grazing is best for infected fescue. *Alabama Agric. Exp. Sta. Highlights Agric. Res.* 35(4):12.
- Bransby, D. I., J. L. Holliman, and J. T. Eason. 1992. Huge weight gain increase from deworming cattle on infected fescue. *Highlights Agric. Res. Agric. Exp. Station, Auburn University, Ala.: The Station.* Winter 39(4):9.

- Brown, M. A., L. M. Tharel, A. H. Brown, W. G. Jackson, and J. R. Miesner. 1993. Milk production in Brahman and Angus cows on endophyte-infected fescue and common Bermuda grass. *J. Anim. Sci.* 71(5):1117.
- Buckner, R. C., J. B. Powell, and R. V. Frankes. 1979. Historic development. Page 1 in *Tall Fescue*. R. C. Buckner and L. P. Bush, ed. Agron. No. 20. Am. Soc. Agron., Madison, WI.
- Buskirk, D. D., D. B. Faulkner, and F. A. Ireland. 1995. Increased postweaning gain of beef heifers enhances fertility and milk production. *J. Anim. Sci.* 73:937.
- Carr, S. B., and D. R. Jacobson. 1969. Bovine physiological responses to toxic tall fescue and related conditions for application in a bioassay. *J. Dairy Sci.* 52:1792.
- Chestnut, A. B., H. A. Fribourg, J. B. McLaren, D. G. Keltner, B. B. Reddick, R. J. Carlisle, and M. C. Smith. 1991. Effects of *Acremonium coenophialum* infestation, bermudagrass and nitrogen or clover on steers grazing tall fescue pastures. *J. Prod. Agric.* 4:208.
- Crawford, Jr., R. J., G. B. Garner, D. H. Wallace, and S. J. Gross. 1990. Effects of continuous ivermectin administration on performance of steers affected by fescue toxicosis. *J. Anim. Sci.* 68(Suppl.1):561.
- Crawford, Jr., R. J. And G. B. Garner. 1991. Evaluation of corn gluten feed and ivermectin to ameliorate the negative impact of endophyte-infected tall fescue on cattle performance. *Proc Forage Grassland Conference: American Forage and Grassland Council*. Columbia, MO. p. 255.
- Cunningham, I. J. 1949. A note on the cause of tall fescue lameness in cattle. *Aust. Vet. J.* 25:27.
- Daniels, L. B., A. Ahmed, T. S. Nelson, et al. 1984. Physiological responses in pregnant white rabbits given a chemical extract of toxic tall fescue. *Nutr. Rep. Int.* 29:505.
- Danilson, D. A., S. P. Schmidt, C. C. King, L. A. Smith, and W. B. Webster. 1986. Fescue toxicity and reproduction in beef heifers. *J. Anim. Sci.* 63 (Suppl. 1):296(Abstr.).
- Elsasser, T. H. and D. J. Bolt. 1987. Dopaminergic-like activity in toxic fescue alters prolactin but not growth hormone or thyroid stimulating hormone in ewes. *Domest. Anim. Endo.* 4:259.
- Entrocasso, C., D. Parra, D. Vottero, M. Farias, L. F. Uribe, and W. G. Ryan. 1996. Comparison of the persistent activity of ivermectin, abamectin, doramectin, and moxidectin in cattle. *Vet. Rec.* 138:91.

- Essig, H. W., C. E. Cantrell, F. T. Withers, Jr., D. L. Lang, D. H. Laughlin, and M. E. Boyd. 1989. Performance and profitability of cow-calf systems grazing on EF and EI KY-31 fescue (preliminary report). Proc. Tall Fescue Toxicosis Workshop, Nov. 13-14, Atlanta, GA.
- Evans, K. L., P. M. Zavos, R. W. Hemkin, et al. 1988. Effects of feeding endophyte-infected (*Acremonium coenophialum*) KY-31 fescue hay on the reproductive development of Holstein bulls. *Theriogenology* 30:169.
- Fluckinger, E. 1975. From our laboratories: Pharmacological characterization of CB 154. *Triangle* 14:153.
- Forcherio, J. C., J. A. Paterson, and M. S. Kerley. 1993. Effects of supplemental energy or protein on rumen parameters and performance of first and second partum beef cows grazing tall fescue. *J. Anim. Sci.* 71(Suppl.1):197(Abstr.).
- Forcherio, J. C., J. A. Paterson, and M. S. Kerley. 1992. Effect of source of supplemental energy and level of rumen undegradable protein on forage intake and performance of cow-calf pairs grazing endophyte-infected tall fescue pasture. *J. Anim. Sci.* 70(Suppl.1):188(Abstr.).
- Garrett, L. 1980. Reproductive problems of mares grazing fescue. Masters Thesis, University of Missouri Press.
- Gay, N., J. A. Boling, R. Dew, and D. E. Miksch. 1988. Effects of endophyte-infected tall fescue on beef cow-calf performance. *Appl. Agric. Res.* 3:182.
- Goodman, A. A. 1952. Fescue foot in cattle in Colorado. *JAVMA* 121:289.
- Hannah, S. M., J. A. Paterson, J. E. Williams, M. S. Kerley, and J. L. Miner. 1990. Effects of increasing dietary levels of endophyte-infected tall fescue seed on diet digestibility and ruminal kinetics in sheep. *J. Anim. Sci.* 68:1693.
- Hannah, S. M., M. T. Rhodes, J. A. Paterson, M. S. Kerley, J. E. Williams, and K. E. Turner. 1989. Influence of energy supplementation on forage intake, digestibility, and grazing time by cattle grazing tall fescue. *Nutr. Rep. Int.* 40:1153.
- Henson, M. C., E. L. Piper, and L. B. Daniels. 1987. Effects of induced fescue toxicosis on plasma and tissue catecholamine concentrations in sheep. *Domestic Animal Endocrin.* 4:7.
- Hoveland, C. S., S. P. Schmidt, C. C. King, Jr., J. W. Odom, E. M. Clark, J. A. McGuire, L. A. Smith, H. W. Grimes, and J. L. Holliman. 1983. Steer performance and association of *Acremonium coenophialum* fungal endophyte on tall fescue pasture. *Agron. J.* 75:821.

- Hoveland, C. S. 1993. Economic importance of *Acremonium* endophytes. *Agric. Ecosyst. & Environ.* 44:3.
- Ireland, F. A., W. E. Loch, K. Worthy, and R. V. Anthony. 1991. Effects of bromocriptine and perphenazine on prolactin and progesterone concentrations in pregnant pony mares during late gestation. *J. Reprod. Fert.* 92:179.
- Jackson, J.A., Jr., R. W. Hempken, J. A. Boling, R. J. Harmon, R. C. Buckner, and L. P. Bush. 1984. Summer fescue toxicity in dairy steers fed tall fescue seed. *J. Anim. Sci.* 58:1057.
- Johnson, M.C., D. L. Dahlman, Siegel, M. R. et al 1985. Insect feeding deterrents in endophyte-infected tall fescue. *Appl. Environ. Microbiol.* 49:568.
- Kitzman, J. V., A. J. Ainsowrth, L. A. Kerr et al. 1986. Experimental treatment of fescue toxicosis in beef cattle. *Miss. Vet. J.* Fall:p.13.
- Kosanke, J. L., W. E. Loch, K. Worthy, and M. R. Ellersieck. 1987. Effect of toxic tall fescue on plasma prolactin and progesterone in pregnant pony mares. *Proc. 10th Equine Nutr. & Physiol. Symp., Fort Collins*, pp. 663.
- Larson, B. T., D. M. Sullivan, M. A. Yordy, J. T. Turner, M. S. Kerley, and J. A. Paterson. 1992. Dopamine D2 receptor density and mRNA are reduced by ingestion of endophyte-infected tall fescue and increased by D2 antagonist injection in rat. *J. Anim. Sci.* 70(Suppl.1):248(Abstr.).
- Larson, R. L., L. R. Corah, M. S. Spire, and R. C. Cochran. 1995. Effect of treatment with ivermectin on reproductive performance of yearling beef heifers. *Theriogenology* 44:189.
- Latch, G. C., M. J. Christensen, and G. J. Sanuels. 1984. Five endophytes of *Lolium* and *Festuca* in New Zealand. *Mycotoxin* 20:535.
- Latch, G. C., L. R. Potter, B. F. Tyler. _____. Incidence of endophytes in seeds from collections of *Lolium* and *Festuca* species. *Ann. Appl. Biol.* 111:59.
- Latch, G. C., M. J. Christensen, and D. L. Gaynor. 1985. Aphid detection of endophyte infection in tall fescue. *New Zealand J. Agric. Res.* 28:129.
- Lipham, L. B., F. N. Thompson, J. A. Stuedemann, and J. L. Sartin. 1989. Effects of metoclopramide on steers grazing endophyte-infected fescue. *J. Anim. Sci.* 67:1090.
- Loch, W. E., L. D. Swantner, and R. R. Anderson. 1987. The effects of four levels of endophyte-infected fescue seed in the diet of pregnant pony mares. *J. Reprod. Fert., Suppl.* 35:535.

- Loch, W., K. Worthy, and F. Ireland. 1990. The effect of phenothiazine on plasma prolactin levels in non-pregnant mares. *Equine Vet. J.* 22(1):30.
- McDonald, W. T. 1989. Performance of cows and calves grazing endophyte-infected pasture. Masters Thesis. University of Tennessee, Knoxville.
- McMurphy, W. E., K. S. Lusby, S. C. Smith, S. H. Muntz, and C. A. Strasia. 1990. Steer performance on tall fescue pasture. *J. Prod. Agric.* 3:100.
- Merriman, G. M., I. A. Dyer, C. S. Hobbs, and M. C. Bell. 1962. Effects of fescue seed and ryegrass seed in rations for yearling beef cattle. *J. Anim. Sci.* 21:232.
- Monroe, J. L., D. L. Cross, L. W. Hudson, D. M. Hendricks, S. W. Kennedy, and W. C. Bridges, Jr. 1988. Effect of selenium and endophyte-contaminated fescue on performance and reproduction in mares. *Equine Vet. Sci.* 8:148.
- Morgan-Jones, G., and W. Gams. 1982. Notes on Hypomycetes XLI. An endophyte of *Festuca arundinacea* and the anamorph of *Epichloe typhira*, a new taxa in one of two sections of *Acremonium*. *Mycotaxon* 15:311.
- Moubarak, A. S., E. L. Piper, C. P. West, and Z. B. Johnson. 1993. Interaction of purified ergovaline from endophyte-infected tall fescue with synaptosomal ATPase enzyme system. *J. Agric. Food Chem.* 41:407.
- Musey, V. C., J. R. K. Preedy, P. I. Musey, M. S. Blank, D. R. Brogan, R. P. Bain, and D. C. Collins. 1986. Prolactin and blood pressure responses to perphenazine in human subjects: comparison of the oral and intramuscular routes. *Am. J. Med. Sci.* 291(6):380.
- Paterson, J., C. Forcherio, B. Larson, M. Samford, and M. Kerley. 1995. The effects of fescue toxicosis on beef cattle productivity. *J. Anim. Sci.* 73:889.
- Pendulum, L. C., J. A. Boling, L. P. Bush, and R. C. Buckner. 1980. Digestibility and metabolism of Kenhy tall fescue harvested at three stages of physiological maturity. *J. Anim. Sci.* 51:704.
- Peters, C. W., K. N. Grigsby, C. G. Aldrich, J. A. Paterson, R. J. Lipsey, M. S. Kerley, and G. B. Garner. 1992. Performance, forage utilization, and ergovaline consumption by beef cows grazing endophyte fungus-infected tall fescue, endophyte fungus-free tall fescue, or orchardgrass pastures. *J. Anim. Sci.* 70:1550.
- Porter, J. K., J. D. Robbins, W. P. Norred, et al. 1985. Serum prolactin and brain catecholamine metabolite depression in rats administered extracts of endophyte-infected fescue. *J. Agric. Food Chem.* 33:34.

- Pratt, A. D., and J. L. Haynes. 1954. Herd performance on Kentucky-31 fescue. *Ohio Farm Res.* 35:10.
- Redmond, L. M., D. L. Cross, T. C. Jenkins, et al. 1991. The effect of *Acremonium coenophialum* on intake and digestibility of tall fescue hay in horses. *Eq. Vet. Sci.* 11:215.
- Redmond, L. M., D. L. Cross, T. Gimenez et al. 1991b. The effect of phenothiazine and withdrawal time on gravid mares grazing endophyte-infected tall fescue. *Eq. Vet. Sci.* 11:17.
- Redmond, L. M., D. L. Cross, and J. R. Strickland et al. 1992. Efficacy of domperidone and sulpiride as treatments for equine fescue toxicosis in gravid mares grazing endophyte-infected tall fescue. *American Society of Animal Science Southern Section Abstracts*: 21.
- Rhodes, M. T., C. G. Aldrich, J. A. Paterson, and M. S. Kerley. 1989. The effect of endophyte-infected tall fescue and a dopamine antagonist on relative blood flow in sheep. *J. Anim. Sci.* 67(Suppl.1):286(Abstr.).
- Rhodes, M. T. 1991. Fescue toxicosis affects blood flow and prolactin. Ph. D. Dissertation. Univ. Of Missouri, Columbia.
- Rhodes, M. T., J. A. Paterson, M. S. Kerley, H. E. Garner, and M. H. Laughlin. 1991. Reduced blood flow to peripheral and core body tissues in sheep and cattle induced by endophyte-infected tall fescue. *J. Anim. Sci.* 69:2033.
- Richards, M. W., J. C. Spitzer, and M. B. Warner. 1986. Effect of varying levels of postpartum nutrition and body condition score at calving on subsequent reproductive performance in beef cattle. *J. Amer. Sci.* 62:300.
- SAS. 1985. *SAS User's Guide: Statistics (Version 5 Ed.)*, SAS Inst. Inc., Cary, NC.
- Samford, M. D., B. T. Larson, M. S. Kerley, J. A. Paterson, and D. M. Lucas. 1994. Influence of dopamine antagonist on serum prolactin, skin and rectal temperature of Holstein calves fed endophyte-infected tall fescue seed diets. *J. Anim. Sci.* 72(Suppl.2):19(Abstr.).
- Schillo, K. K., L. S. Leshin, J. A. Boling, and N. Gay. 1988. Effects of endophyte-infected fescue on concentrations of prolactin in blood sera and the anterior pituitary and concentrations of dopamine and dopamine metabolites in brains of steers. *J. Anim. Sci.* 66:713.
- Sheather, A.L. 1923. The detection of intestinal protozoa and mange parasites by a floatation technique. *Jour. Comp. Path. And Therap.* 36:266.

- Siegel, M. R., M. C. Johnson, D. R. Varney, et al. 1984. A fungal endophyte in tall fescue: Incidence and dissemination. *Phytopathology* 74:932.
- Steen, W. W., N. Gay, J. A. Boling, R. C. Buckner, L. P. Bush, and G. Lacefield. 1979. Evaluation of Kentucky 31, G1-306, G1-307 and Kenhy tall fescue as pasture for yearling steers. II. Growth, physiological response and plasma constituents for yearling steers. *J. Anim. Sci.* 48:618.
- Stidham, W. D., C. J. Brown, L. B. Daniels, et al. 1982. Toxic fescue linked to reduced milk output in ewes. *Ark. Farm Res.* Nov-Dec:9.
- Stoof, J. C. and J. W. Kebabian. 1984. Minireview: Two dopamine receptors: biochemistry, physiology and pharmacology. *Life Sci.* 35:2281.
- Straham, S. R., R. W. Hemken, J. A. Jackson, Jr., et al. 1987. Performance of lactating dairy cows fed tall fescue forage. *J. Dairy Sci.* 70:1228.
- Strickland, J. R. 1990. Large milkweed bug (*Oncopeltus fesciatus*) bioassay of toxins associated with endophyte (*Acremonium coenophialum*) infected tall fescue (*Festuca arundinacea*) forage or seed. Masters thesis. Clemson University, Clemson, SC.
- Strickland, J. R., J. W. Oliver, and D. L. Cross. 1993. Fescue toxicosis and its impact on animal agriculture. *Vet. Human Tox.* 35(5):454.
- Stuedemann, J. A., and C. S. Hoveland. 1988. Fescue endophyte: History and impact on animal agriculture. *J. Prod. Agric.* 1:39.
- Swantner, L. D. 1986. Tall fescue effects on composition of the placenta. Masters Thesis, University of Missouri Press.
- Taylor, M. C., W. E. Loch, and M. R. Ellersieck. 1985. Toxicity in pregnant pony mares grazing Kentucky-31 fescue pastures. *Nutr. Rep. Int.* 31:787.
- Tucker, C. A., R. E. Morrow, J. R. Gerrish, C. J. Nelson, G. B. Garner, V. E. Jacobs, W. G. Hires, J. J. Shinkle, and J. R. Forwood. 1989. Forage systems for beef cattle: Effect of winter supplementation and forage system on reproductive performance of cows. *J. Prod. Agric.* 2:217.
- Turner, K. E., J. A. Paterson, M. S. Kerley, and J. R. Forwood. 1990. Mefluidide treatment of tall fescue pastures: Intake and animal performance. *J. Anim. Sci.* 68:3399.
- Waller, J. C. J. B. McLaren, H. A. Fribourg, A. B. Chestnut, and D. G. Keltner. 1989. Effect of *Acremonium coenophialum* infected *Festuca arundinacea* on cow-calf production. In: *Proc. 16th Int. Grassl. Congr.*, Oct. 4-11, Nice, France. p. 1193.

- Walls, J. R., and D. R. Jacobson. 1970. Skin temperature and blood flow in the tail of dairy heifers administered extracts of toxic tall fescue. *J. Anim. Sci.* 30:420.
- West, C. P., E. Izekor, S. M. Oosterhuis et al., 1987. Endophytic fungus effects on tall fescue tolerance of drought and nematodes. *Ark. Farm Res.* 36:3.
- White Jr., J. F. And G. T. Cole. 1985. Endophyte-host associations in forage grasses. III. In vitro inhibition of fungi by *Acremonium coenophialum*. *Mycologia* 77:487.
- Wiseman, B. S., D. L. Vincent, P. J. Thomford, N. S. Scheffrahn, G. S. Sargent, and D. J. Kesler. 1982. Changes in porcine, ovine, bovine and equine blood progesterone concentrations between collection and centrifugation. *Anim. Reprod. Sci.* 5:157.
- Yates, S. G., J. C. Fenster, and R. J. Bartelt. 1989. Assay of tall fescue seed extracts, fractions, and alkaloids using the large milkweed bug. *J. Agric. Food Chem.* 37:354.
- Zavos, P. M., D. R. Varney, J. A. Jackson, et al. 1988. Lactation in mice fed endophyte-infected tall fescue seed. *Theriogenology* 30:865.

Table 1. The effect of ivermectin and pasture endophyte level on rectal temperatures for Trial 1.

Item	Control		Ivermectin		SE
	Endophyte		Endophyte		
	Low	High	Low	High	
Rectal temp, °C					
d 0	40.3	40.5	40.6	40.4	.1
d 42	38.7 ^a	39.2 ^b	38.7 ^a	39.1 ^b	.1
d 58	40.4 ^a	41.0 ^b	40.9 ^b	40.9 ^b	.2
Change	.1 ^a	.6 ^b	.3 ^{ab}	.5 ^b	.1

^{a,b}Least squares means within a row with different superscripts differ ($P < .05$).

Table 2. Mean weekly weather data for Trial 1.

	Average Maximum Temperature	Average Minimum Temperature	Average Maximum Humidity	Average Minimum Humidity
Week 1 (day 0 to +7)	89	68	83	45
Week 2	82.7	60	83	44
Week 3	84	61.5	82	43.7
Week 4	89	66.7	83.5	47.4
Week 5	84.4	59.1	84.2	47.7
Week 6	87	61	84	55.4
Week 7	82.8	59	83	52.4
Week 8	82.7	58.5	85	42.8
Week 9	89.3	60.3	84.6	39

Table 3. Serum prolactin (ng/ml) concentrations for Trial 1.

Item	Control		Ivermectin		MSE
	Endophyte		Endophyte		
	Low	High	Low	High	
d 0 - 0800h	50.01	85.2	60.42	74.3	50.5
d 0 - 1300h	72.49	69.12	65.26	64.52	31.7
d 2	117.02	112.64	90.86	97.57	43.1
d 9	108.08	53.14	91.55	57.52	48.0
d 18	45.64	19.78	63.04	20.75	32.8
d 28	42.0	20.33	52.96	31.04	25.2
d 42	54.45	55.91	59.38	42.86	
d 58	13.65	7.44	11.76	15.62	

These values are means not LS means.

Table 4. ADG and serum prolactin concentrations by treatment for Trial 2.

	n	Trt 1: CGF	Trt 2: Zeranol + CGF	Trt 3: Zeranol	Trt 4: HE Control	Trt 5: LE Control	SEM
ADG (kg/(hd•day))	20	0.55 ^a	0.61 ^a	0.53 ^a	0.40 ^b	0.53 ^a	0.09
Prolactin (ng/ml)							
d 0	119	35.96	30.97	28.53	33.93	33.20	4.13
d 35	119	25.88 ^c	21.03 ^c	16.32 ^c	24.93 ^c	85.93 ^d	9.20
d 63	118	11.20 ^c	7.26 ^c	4.13 ^c	8.08 ^c	47.64 ^d	6.95

Least squares means.

CGF = corn gluten feed.

HE = high endophyte tall fescue.

LE = low endophyte tall fescue.

^{a,b}Means in the same row with different superscript letters differ ($P < .05$).

^{c,d}Means in the same row with different superscript letters differ ($P < .01$).

Forage availability was estimated to be adequate for the trial period.

Table 5. Mean weekly weather data for Trial 2.

	Average Maximum Temperature	Average Minimum Temperature	Average Maximum Humidity	Average Minimum Humidity
Week 1 (day 0 to +7)	93.4	71.8	88.4	50.7
Week 2	88	67.4	87.1	51.7
Week 3	90.5	69.7	88.4	57.5
Week 4	89.7	71.2	89.1	60.5
Week 5	92.1	70.7	89.5	59.2
Week 6	94.7	75.1	89.7	57.2
Week 7	90.5	65	87	38.7
Week 8	91.2	62.8	87.8	39
Week 9	84	60.7	88.1	47.5
Week 10	84.8	61.8	86.2	46.4
Week 11	74.6	57.6	88.6	55.3

Table 6. Trial 3 performance data for Trial 3 by cow treatment.

	IVO	CON	SE
Initial cow wt (kg)	444.4	443.4	
Cow wt gain (kg)	5.18	1.18	2.79
Initial cow BCS (1-9)	4.76	4.64	
Change in cow BCS	.059	.246	.117
PRL1 (d 0)	45.33	49.87	5.45
PRL 2 (d 35)	47.33	37.32	5.06
PRL 3 (d 71)	1.40	2.13	.363
Change in milk prod. (kg) (d 1-d 35)	-0.84 ^a	-1.46 ^b	.199
Ending preg status (% preg)	.824	.775	.071
Initial calf wt (kg)	138.25	141.7	
Change in calf wt (kg)	48.61	46.69	1.93
Calf ADG (kg)	.68	.65	.03
Initial calf hip ht (cm)	98.75	99.18	
Change in calf hip ht (cm)	36.81	35.99	1.41

^{a,b}Means in the same row with different superscript letters differ ($P < .03$).

Table 7. Trial 3 performance data for Trial 3 by calf treatment.

	IVO	CON	SE
Initial calf wt (kg)	143.9	136.0	
Change in calf wt (kg)	48.7	46.6	1.96
Calf ADG (kg)	.69	.66	.03
Initial calf hip ht (cm)	105.23	103.83	
Change in calf hip ht (cm)	36.64	36.174	1.43

SITES OF DIGESTION IN STEERS GRAZING TALL FESCUE AND SUPPLEMENTED WITH ENERGY AND PROTEIN

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SUMMARY

The effects of different types and levels of energy supplementation on sites of OM and N digestion in steers grazing the spring growth of tall fescue (*Festuca arundinacea* Schreb.), were determined. Four Angus x Simmental steers fitted with cannulas at the esophagus, rumen, and duodenum were assigned to: grazing tall fescue (C), C + 3.1 kg corn gluten feed (CGF), C + 3.1 kg cracked corn (CC), or C + 1.4 kg corn starch and corn gluten meal mixture 50% each (CSCGM) in periods of 8 days for adaption and 6 for measurements. Supplementation (S) tended to decrease ruminal pH (C: 6.4, S: 6.3; $P < .12$) and NH_3 (C: 21.9, S: 19.4; $P < .1$) but had no effect on VFA concentration (average: 100 Mmol/L). Forage OM intakes tended to be lower ($P < .12$) in the supplemented animals (C: 9,658 g/d; S: 8,658 g/d) and tended to be higher ($P < .07$) in CSCGM (9,458 g/d) than in CGF and CC (average: 7,578 g/d) but total OM intakes were not increased by supplements (average: 10,410 g/d). Supplementation tended to increase N intakes (C: 310.7 g/d; S: 361.6 g/d; $P < .16$) and were higher for CSCGM than for CGF and CC ($P < .05$) but supplements did not increase duodenal N flows (average: 228.4 g/d). Microbial synthesis (g N/kg OM apparently digested in rumen) was not affected by treatments (average: 40.5 g/kg) as well as total duodenal amino acid flow (average: 1086 g/d). Supplementation of high quality tall fescue at grazing tended to reduce forage OM intake but did not seem to cause a reduction on the utilization of forage OM components. Supplements did not reduce the ruminal N losses because N intakes were not reduced compared to the control. Flows of N to the duodenum were in excess relative to digestible OM intakes suggesting that animal performance could still be limited by OM intakes even with high ruminal N losses.

INTRODUCTION

Forages with high N contents are often considered to supply all the CP required by high producing animals. However, much of this CP never reaches the small intestine due to the high losses of ruminally degraded CP. Duodenal flows could be increased by enhancing microbial CP synthesis using energy supplements. Corn grain is commonly used as a high energy high starch supplement. However, corn gluten feed (CGF) has high fiber content as well as high digestibility which may avoid reductions in forage fiber digestion observed with corn grain. For these reasons our objectives were to evaluate the effects of levels and sources of energy supplementation for stocker steers grazing the first growth of tall fescue.

PROCEDURES

Four Angus x Simmental crossbred steers (412 ± 20.4 kg) fitted with cannulas at the esophagus, rumen and proximal duodenum were used. Before (April 4 to April 13) and during the experiment (April 13 to June 7) steers grazed a endophyte-infected tall fescue pasture in a 4 x 4

Latin Square design with 14 d periods (8 d pre-experimental and 6 d for sampling). Supplements used were cracked corn (CC), CGF, and a mixture of 1:1 corn starch (CS) and corn gluten meal (CSCGM). The level of metabolizable energy (ME) was calculated from the ME values (NRC, 1984) for each supplement: 3.25, 2.99, and 3.11 Mcal of ME/kg DM for CC, CGF, and CSCGM respectively. The amount of escape protein (EP) was calculated according to the CP content of each supplement and their estimated ruminal undegradabilities (NRC, 1985): 64, 32, and 60% for CC, CGF, and CGM respectively. Different levels of supplement were established in order to supply different amounts of ME at constant EP (Table 1).

Supplements were given in two meals at 7 a.m. and 7 p.m. and at the same time chromic oxide (7.308 g of Cr/d) was dosed into the rumen in order to estimate duodenal flows and fecal output beginning dosing on d 3 of the experimental period. Masticated samples were collected in each steer on d 9, 11, 12, 13, and 14 at 6 am and composited by steer and period. Duodenal samples were collected at four times a day during 6 days, frozen, and then thawed and composited by steer and period. Composite samples were freeze dried, ground in a Wiley mill through 1 mm mesh and stored for analysis. Fecal grab samples were collected using the same schedule and processing as the duodenal samples.

Fifty mL of ruminal fluid samples was obtained on d 10 at 3 a.m., 7 a.m., 9 a.m., noon, 3 p.m., 7 p.m., and 9 p.m. and ruminal fluid pH was measured immediately. Samples were acidified with 3 mL of 6 N HCl and frozen for later analysis of VFA and NH₃-N. A bacteria rich fraction was additionally isolated from whole rumen contents.

Masticate, duodenal, bacteria, fecal, and supplement samples were analyzed for DM and OM. Fecal and dietary samples were analyzed for indigestible ADF (IADF) using 96 h of in vitro incubation. All samples were analyzed for Kjeldahl N and duodenal and bacteria samples were analyzed for purines and amino acids were determined in duodenal samples.

Chromium concentration in duodenal and fecal samples were determined by atomic absorption spectroscopy. Total VFA concentration was the sum of acetate, propionate, butyrate, isobutyrate, valerate, and isovalerate concentrations. Molar proportions were calculated as concentration of individual VFA/concentration of total VFA.

Apparent OM digestibility was calculated as $(100 - [IADF \% \text{ feed} / IADF \% \text{ feces}] * 100)$.

Data were analyzed as a Latin Square design and ruminal ammonia N, pH and VFA concentrations were analyzed for a split-plot design with repeated measurements. Orthogonal contrasts were evaluated for comparing control vs supplemented, level of energy (CSCGM vs CC and CGF) and type of energy (GC vs CGF). For the chemical composition of the esophageal masticate samples, linear and quadratic effects due to period were tested.

RESULTS AND DISCUSSION

Advancing forage maturity increased the cell wall components and decreased the N content of extrusa samples (Table 2). An increase in cell wall components (NDF and ADF) in the extrusa

has been reported in some experiments (Howard et al., 1992), but not in others (McCracken et al., 1993). In our study even when N contents linearly decreased with advancing maturity the contents remained higher than the values usually reported for tall fescue during the spring in extrusals (McCracken et al., 1993). Part of these differences could be explained by the degree of selectivity that animals can make at grazing depending on grazing pressure, structure of the pasture. Total OM intakes, although numerically higher, were not different for the supplemented animals (Table 3). However, forage intake tended to be lower when supplements were used and when CGF and CC were compared with CSCGM. Hess et al. (1993) supplemented corn or wheat bran in animals grazing tall fescue reported a reduction in forage intake by not in the total DM intakes suggesting also replacement effects.

Supplements represented 27.7 %, 28.4 % and 13.4 % of total DM intakes for CGF, CC, and CSCGM respectively. Rates of substitution were .78 and .63 kg forage/kg CGF or CC respectively. Forage OM intake tended to be higher in CSCGM compared with CGF or CC and it was not different to that of the animal grazing tall fescue alone, leading to a lower substitution rate (.14 kg forage/kg CSCGM).

Total OM digestibility was not different among treatments and also for the digestible OM intakes (DOMI). However, the difference in DOMI between supplemented (mean: 8,608 g/d and control: 7,619 g/d) could be enough for increasing ADG of 280 g/d (NRC, 1984) for medium frame (450 kg) steers (assuming TDN = DOMI) gaining 600 g/d. There were no differences in total OM flowing to the duodenum as well as in the proportion of DOMI that was apparently or truly digested in the rumen suggesting that supplements were unable to change the sites of OM digestion of high quality tall fescue.

Total N intakes tended to be higher ($P < .16$) in the supplemented animals and was higher ($P < .05$) for those supplemented with CSCGM compared with CC and CGF (Table 4). Moreover, N content in the total diet (forage plus concentrates) tended to be lower in the CC compared with CGF or CSCGM in response to the different N contents of supplements used (Table 1). However, the N content of the total diet was not different between control and supplemented. Hence, CC given as a source of energy didn't reduce N intakes with respect to the control.

There were no differences in the duodenal N flow, except that flows tended to be higher at the CS-CGM than other supplements. This may be a response to an increased forage intake compared with other supplements. There were no differences in the N flows related with N intakes or for each kg of DOMI or OMADR as well as in digestibility. Energy supplements seemed to not reduce N losses due to supplementation, and did not affect the N % in the total diet even in CC. Microbial efficiencies in relation to the OM degraded were higher than the mean value of 30g/kg OM apparently digested in rumen (ARC, 1980) and close to those found by Corbett and Pickering (1983) for different forages. There were no differences in the contribution of bacterial N to the total duodenal flow.

According to the DOMI steers grazed enough forage to achieve an ADG of 1 kg/d, assuming DOM equal to TDN (NRC, 1984). From the estimation of the NRC (1985) the duodenal flow

of bacteria and dietary N was enough to make medium frame steers gain more than 1.80 kg/d. Animal performance in high quality tall fescue may not be limited by the amount of protein that reaches the duodenum. Organic matter intakes or energy might still be first limiting for animal performance.

Duodenal nonessential and essential amino acids were not affected by the supplements (Table 5). These data indicate that grazed tall fescue provided the same amount of amino acids to the duodenum as supplemented animals particularly for those amino acids considered limiting amino acids like lysine, methionine and threonine. If the same amount of amino acids were provided by all treatments and in the performance study the ADG were higher in the supplemented ones than in the controls (Elizalde et al., 1995), the increased production could be due to the energy supply more than to the protein supply.

Ruminal pH tended to decrease with supplements ($P < .12$), but there were no differences among them (Table 6). Even so, pH values were in the range considered not detrimental for fiber digestion. Forcherio et al. (1993) found that supplements tended to reduce pH from 6.42 in animals fed with spring growth of tall fescue to 6.31 in the supplemented animals.

There was a tendency for a lower $\text{NH}_3\text{-N}$ concentration in the supplemented animals but the values indicate that supplements had little effect on reducing ruminal $\text{NH}_3\text{-N}$ concentration. The N intakes as well as the duodenal flows were not different between treatments giving similar N losses and $\text{NH}_3\text{-N}$ concentrations.

Supplementation didn't have an effect on the total concentration and proportions of VFA in rumen as well as in the Acetate:Propionate ratio and could be an indication of similar pattern of fermentation across treatments. Hess et al. (1993) found that even when there are some differences between supplemented and control in the VFA patterns in animals grazing tall fescue, energy supplementation for cattle grazing high quality forages does not cause deleterious effects on forage utilization.

CONCLUSIONS

Supplementation at grazing caused a reduction of the intake but not of the digestion of high quality grazed tall fescue. The duodenal N flows did not increase with supplementation because supplements did not reduce N intakes. Even with high ruminal N losses animals were still not protein deficient and performance seems to be limited by digestible OM intake or energy.

REFERENCES

- Agricultural Research Council. 1980. The Nutrient Requirements of Ruminant Livestock, Commonwealth Agricultural Bureau, Farnham Royal.
- Corbett, J.C.L. and F.S. Pickering. 1983. Rumen microbial degradation and synthesis of protein in grazing sheep. In: G.E. Robards and R.G. Packham (Ed.). Feed Information and Animal Production. C.A.B. UK p. 301.

- Elizalde, J.C., D.B. Faulkner, and N.R. Merchen. 1995. Effects of supplementation of grazing steers with protein and energy on body weight gains and carcass composition. Illinois Beef Res. Rep. p. 27
- Forcherio, J.C., J.A. Paterson, and M.S. Kerley. 1993. Effects of supplemental energy or protein on rumen parameters and performance of first and second partum beef cows grazing tall fescue. J. Anim. Sci. 71 (Suppl. 2):429 (Abstr.).
- Hess, J.D., B.W. Hess, L.J. Krysl, M.B. Judkins, D.R. Hunks, and S.A. Huber. 1993. Supplemental cracked corn or wheat bran for steers grazing fescue pasture. I. Effects on animal performance, intake and digesta kinetics. J. Anim. Sci. 71 (Suppl. 2):427 (Abstr.).
- Hess, B.W., L.J. Krysl, M.B. Judkins, J.D. Hess, D.R. Hanks, and S.A. Huber. 1993. Supplemental cracked corn or wheat bran for steers grazing fescue pasture. II. Effects on ruminal fluid kinetics and fermentation. J. Anim. Sci. 71 (Suppl. 2):428 (Abstr.).
- Howard, M.D., R.B. Muntifering, N.W. Bradley, G.E. Mitchell, Jr., and S.R. Lowry. 1992. Voluntary intake and ingestive behavior of steers grazing Johnstone or endophyte-infected Kentucky-31 tall fescue. J. Anim. Sci. 70:1227.
- McCracken, B.A., L.J. Krysl, K.K. Park, D.W. Holcombe, and M.B. Judkins. 1993. Steers grazing endophyte-free tall fescue: seasonal changes in nutrient quality, forage intake, digesta kinetics, ruminal fermentation, and serum hormones and metabolites. J. Anim. Sci. 71:1588.
- NRC. 1984. Nutrient Requirements of Beef Cattle (6th Ed.). National Academy Press, Washington, DC.
- NRC. 1985. Ruminant Nitrogen Usage. National Academic Press, Washington, DC.

Table 1. Chemical composition and estimated escape protein and metabolizable energy in the supplements used in the digestion study.

Item	CGF	CC	CS-CGM
OM, % DM	91.3	98.1	94.19
	-----% OM -----		
	3.98	1.51	5.77
NDF	39.9	21.3	11.82
ADF	11.01	2.6	4.52
Total fed (kg/hd/d)	3.11	3.11	1.55
Estimated EP (g/hd/d)	200.0	200.0	200.0
Estimated ME (Mcal/hd/d)	9.33	10.1	4.87

OM: organic matter, N: nitrogen, NDF and ADF: neutral and acid detergent fiber, respectively; EP: escape protein; ME: metabolizable energy.

Table 2. Chemical composition (% of OM) esophageal extrusa samples of steers grazing the primary growth of tall fescue through the different experimental periods.

Item	Period ^a				SEM ^b	Effect ^c
	P ₁	P ₂	P ₃	P ₄		
OM, % of DM	85.2	84.8	80.7	84.5	1.22	NS
	-----% OM -----					
TN	3.9	3.6	3.1	2.7	.1	L***
NDF	60.4	64.0	71.2	74.7	2.6	L***
ADF	26.6	28.6	37.4	35.6	1.2	L***
ADL	4.3	4.7	10.4	5.8	1.2	L*,Q*

^aAverage of extrusa samples for each period.

^bStandard error of the mean.

^cL = linear; Q = quadratic effect of time; ***P < .01, ** < .05, *P < .1, NS = nonsignificant.

Table 3. Intake and site and extent of OM digestion in supplemented steers grazing tall fescue pasture.^a

	Treatments ^b					Statistical Effect ^d	
	C	CGF	CC	CS-CGM	SE ^c	C vs S	CS-CGM vs CGF, CC
Intake, g/d							CGF vs CC
Forage	9,658	7,430	7,726	9,453	.72	.12	.78
Supplement		2,848	3,061	1,467			
Total	9,658	10,278	10,786	10,920	.75	.27	.63
Duodenal flow, g/d	3,968	4,550	4,246	4,695	.72	.55	.78
Fecal, g/d	2,038	2,120	1,958	2,088	.21	.95	.63
Total digestibility	77.5	78.8	81.9	80.7	2.3	.3	.37
Digestible OM intake	7,619	8,166	8,827	8,831	.68	.24	.51
Digestion, % of total							
-Ruminal apparent	69.2	65.1	73.7	68.7	3.6	.99	.41
-Ruminal true	95.5	94	97	97.3	4.9	.83	.49

^aLeast squares means; n = 4.

^bC: tall fescue alone, CGF: C plus 3.1 kg/d corn gluten feed, CC: C plus 3.1 kg/d cracked corn, CSGM: C plus 1.55 kg/d of corn starch - corn gluten meal mixture (equal basis).

^cStandard error of mean.

^dOrthogonal contrasts with P values for each comparison, S: supplements.

Table 4. Nitrogen intake and digestion, and ruminal microbial synthesis in supplemented steers grazing tall fescue.^a

	Treatments ^b					Statistical Effect ^d		
	C	CGF	CC	CS-CGM	SE ^c	C vs S	CS-CGM vs CGF,CC	CGF vs CC
Intake, g/d								
Forage	310.7	241.9	264.8	317.5	22.7	.3	.06	.49
Supplement	-	123.8	46.9	89.8				
Total	310.7	365.7	311.7	407.3	22.9	.16	.05	.14
N in total diet (OM%)	2.75	3.04	2.54	3.18	.11	.34	.03	.02
Duodenal flow								
-g/dl	217.4	225.7	215.8	254.7	11.7	.41	.06	.57
-g/g Nl ^e	.72	.62	.70	.63	.06	.33	.66	.31
-g/kg DOMI ^f	29.6	28.3	24.7	29.5	2.5	.57	.36	.35
-g/kg OMADR ^g	39.9	46.1	38.1	43.7	5.8	.75	.83	.38
Microbial N								
-g/g duodenal N	.69	.76	.69	.63	.05	.33	.53	.38
-g/kg OMADR	40.4	44.2	34.3	43	8.8	.99	.74	.45
-Fecal N, g/d	110.9	88.8	93.3	106.8	8.4	.27	.18	.72
Digestion, % of intake								
-Total tract	64.3	75.7	70.1	73.7	3.2	.54	.36	.61

^aLeast squares means; n = 4.

^bC: tall fescue alone, CGF: C plus 3.1 kg corn gluten feed, CC: C plus 3.1 kg cracked corn, CSCGM: C plus 1.55 kg of corn starch - corn gluten meal mixture (equal basis).

^cStandard error of mean.

^dOrthogonal contrasts with p values for each comparison, S: supplements.

^eNI: N intake.

^fDOMI: digestible OM intake.

^gOMADR: OM apparently digested in rumen.

Table 5. Amino acid analysis in duodenal samples in steers grazing tall fescue as influenced by supplementation.^{a,b}

	Treatments ^b					Statistical Effect ^d		
	C	CGF	CC	CSCGM	SE ^c	C vs S ^d	CS-CGM vs CGF,CC ^d	CGF vs CC ^d
Nonessential (NESS)								
Alanine	79.4	74.4	71.2	83.2	7.63	.73	.30	.77
Aspartic acid	122.0	112.4	104.7	123.3	8.2	.40	.19	.53
Glutamic acid	168.7	148.2	141.7	179.7	20.9	.63	.22	.83
Glycine	79.4	73.3	68.0	77.2	6.2	.38	.41	.56
Proline	63.7	56.8	53.3	67.8	9.52	.7	.31	.80
Serine	25.5	24.5	22.5	25.0	2.6	.61	.67	.59
Total NESS	538.9	489.7	461.4	556.1	52.3	.56	.25	.71
Essential (ESS)								
Arginine	52.9	46.1	42.3	50.5	3.6	.16	.21	.47
Histidine	30.6	27.6	27.2	32.7	3.7	.74	.28	.94
Valine	72.3	69.7	62.0	70.5	5.3	.45	.50	.34
Leucine	118.2	105.2	101.1	124.6	13.8	.63	.25	.84
Isoleucine	67.8	62.7	56.7	67.1	9.6	.32	.23	.39
Phenylalanine	72.3	66.9	68	78.8	6.3	.89	.19	.90
Tyrosine	49.7	39.8	38.4	49.7	2.0	.17	.06	.80
Threonine	44.9	42.1	38.2	44.1	3.6	.42	.39	.47
Methionine	18.5	17.7	16.3	18.3	7.8	.61	.55	.61
Lysine	81.4	73.9	73.4	83.1	6.0	.53	.24	.95
Total ESS	608.7	551.7	523.5	619.6	8.5	.46	.21	.69
Total AA	1,147	1,041	984.0	1,175	100	.51	.23	.70

^aLeast squares means; n = 4.

^bC: tall fescue alone, CGF: C plus 3 kg corn gluten feed, CC: C plus kg cracked corn, CSCGM: C plus 1.5 kg of corn starch - corn gluten meal mixture (equal basis).

^cStandard error of mean.

^dOrthogonal contrasts with p values for each comparison, S: supplemented.

Table 6. Rumen pH, ammonia N and VFA concentrations as influenced by supplements in steers grazing tall fescue.^{a,b}

	Treatments ^b					Statistical Effect ^d		
	C	CGF	CC	CSCGM	SE ^c	C vs S ^d	CSCGM vs CGF, CC ^d	CGF vs CC ^d
pH ^d	6.4	6.3	6.3	6.3	.08	.12	.84	.93
Ammonia N, mg/dL	21.9	18.5	19.8	20.0	3.0	.10	.58	.47
Total VFA, mM/100mL	98.2	101.2	101.5	101.7	5.4	.27	.89	.93
VFA, mM/100mM								
Acetate	60.6	61.6	62.7	61.5	2.9	.42	.69	.58
Propionate	17.5	17.5	17.9	17.5	1.1	.94	.85	.77
Butyrate	10.7	10.9	11.2	11.2	.98	.59	.90	.70
Isobutyrate	1.3	1.2	1.3	1.2	.05	.20	.62	.51
Valeric	8.2	7.2	5.2	6.9	1.1	.30	.68	.36
Isovaleric	1.6	1.5	1.7	1.7	.11	.78	.58	.28
Acetate:Propionate	3.46	3.53	3.52	3.52	.09	.67	.99	.95

^aLeast squares means; n = 4.

^bC: tall fescue alone, CGF: C plus 3.1 kg corn gluten feed, CC: C plus 3.1 kg cracked corn, CSCGM: C plus 1.55 kg of corn starch - corn gluten meal mixture (equal basis).

^cStandard error of mean.

^dOrthogonal contrasts with p values for each comparison, S: supplements.

EFFECTS OF MORNING VS. EVENING FEEDING OF WET CORN GLUTEN FEED DIETS TO BEEF CATTLE

A. E. Wertz, L. L. Berger, and T. G. Nash

SUMMARY

Weather conditions can have a substantial influence on the performance of feedlot cattle. Recent research has revealed that summer-finished cattle fed in the evening, allowed to digest and release the greatest heat of fermentation during the coolest part of the day, had improved average daily gains (ADG) and feed efficiencies (G:F). These improvements were attributed to the lack of energy required to dissipate the heat generated from fermentation which occurs in the warmest part of the day for morning-fed cattle. To test if similar benefits would result for evening-fed cattle during the winter months in Illinois, one hundred and ninety-two beef heifers were assigned to a feeding time of either 8:00 am or 4:00 pm from early October to early March. The trial was divided into a growing phase and a finishing phase which were dictated by the type of diet being fed. Diets were fed *ad libitum* and the cattle had *ad libitum* access to water. Dry matter intakes and refusals were recorded and the cattle were weighed at 28 d intervals throughout the duration of the trial. No improvements in ADG or G:F were observed for the heifers in either the growing or finishing phase of the trial. However, it should be considered that this was a relatively mild Illinois winter and a more prevalent effect may have resulted with more severe conditions.

INTRODUCTION

Fluctuation in weather conditions can markedly decrease average dry matter intakes (ADMI) as well as modify the cyclic body temperature patterns of *Bos taurus* cattle. Ultimately, these fluctuations have an impact on the growth, efficiency, and health of the animal (DeDios and Hahn, 1992). Temperature alone is not an adequate indicator of the stress that weather can have on the performance of beef cattle. Humidity, wind speed, and precipitation in combination with air temperature have the greatest influence on beef cattle performance (Hahn, 1985). The thermoneutral zone, the range of temperature at which beef cattle maintain homeostasis, ranges from 15 to 25° C. Ambient temperature outside this range requires expenditure of the animal's energy to maintain homeostasis (Reinhardt and Brandt, 1994).

Votes and Pritchard (1994) found that feeding beef steers in the evening during the South Dakota summer increased their average daily gain (ADG) and improved their feed efficiency. Reinhardt and Brandt (1994) obtained similar results when evening-feeding Holstein steers high grain diets for 56 d. They reported an 18% improvement in ADG which tended to result in improved feed efficiencies. These findings were attributed to the thermodynamics of digestion and metabolism. Ruminal fermentation of high grain diets peaks within the first 12 h after consumption. Therefore the greatest heat of fermentation, for the evening-fed cattle, was lost during the coolest part of the day. This resulted in improved performance because additional energy was not required to dissipate heat, resulting from digestion and metabolism which occurred during the warmest part of the day for the morning-fed cattle (Reinhardt and Brandt, 1994). Similarly, cold weather can affect ADG and the feed efficiency of beef cattle. Hahn (1985) reported a 3-5% increase in the

cost of feed to produce the same pounds of beef in severe cold weather with above normal snow fall.

This trial was initiated to determine if the improvements in ADG and G:F, for beef steers fed during the evening in the summer, would also be prevalent in beef heifers fed growing or finishing diets containing WCGF in the evening during the winter months in Illinois. WCGF is higher in fiber than the corn it is replacing and will have a higher heat increment. This heat increment may be advantageous if available during times of cold stress.

MATERIALS AND METHODS

One hundred and ninety-two crossbred beef heifers were allotted in a completely randomized block design to determine the effects of morning vs. evening feeding on rate of growth and feed efficiency. This trial was initiated in early October and terminated in early March. The trial was composed of a growing phase and a finishing phase. Each phase being characterized by the type of diet fed. The growing diet was a corn silage based diet (Table 1) and was fed for 102 d. The corn silage was gradually replaced with high-moisture corn until the final finishing diet was reached (Table 2). One half of the pen allotments were fed at 8:00 am (AM) and the remaining were fed at 4:00 pm (PM). The cattle had ad libitum access to feed and water. Dry matter intakes and refusals were monitored and recorded for each pen on a daily basis.

Cattle were weighed at trial initiation and termination and intermediate weights were taken at 28-d intervals throughout the duration of the trial. Approximately 12-h prior to the initial weighing, cattle were withheld from feed to reduce variation due to gut fill. Similarly, for two feedings prior to termination of growing phase, cattle were restricted to 75% of the DMI for the lowest consuming pen. The finishing phase was terminated at slaughter and hot carcass weights (HCWT) were recorded at this time. Final live weight was calculated by dividing the carcass weight by an average dressing percentage of 62%.

Data collected were analyzed using analysis of variance procedures for a completely randomized block design according to the General linear Models of SAS (1985). Differences in treatment means resulting from time of feeding were separated using Least Squared Means methods of SAS.

RESULTS

Time of feeding during the growing phase did not have an affect on rate of gain or feed efficiency of gain. However, the AM cattle tended ($P < .10$) to have lower average dry matter intakes (ADMI) (Table 3). Cattle fed in the morning during the finishing phase had heavier carcasses ($P < .05$). However, they did not have a significantly faster rate of growth or improved feed efficiency (Table 4). Upon interpreting these results it should be considered that the winter was relatively mild for this particular climate. A difference in ADG or G:F may have been more apparent with greater cold stress. In conclusion, when feeding once per day, a corn silage based growing diet or a high-moisture corn based finishing diet containing 40% WCGF, there were no differences in cattle performance between morning and evening feedings, during a mild winter in Illinois.

REFERENCES

- DeDios, O.O. and G.L. Hahn. 1992. Thermoregulation and acclimatization of feedlot cattle during the transition from summer to winter season. Beef Research Report Meat Animal Research Center. Clay Center, NE.
- Hahn, G.L. 1985. Weather and climate impacts on beef cattle. Beef Research Progress Report No. 2. Roman L. Hruska U.S. Meat Animal Research Center.
- Knutsen, J.S., J.J. Vetos, R.H. Pritchard. 1994. Effects of morning, evening, and twice daily feeding on feedlot performance of steers. J. Anim. Sci.72:698 Suppl 1.
- Reinhardt, C.D. and R.T. Brandt, Jr. 1994. Effects of morning vs. evening feeding of limited Holsteins during the summer months. Kansas State University Cattlemen's Day 1994.

Table 1. Growing diet composition on a dry matter basis.

Ingredient	Percent of Diet
Corn silage	52.5
Wet corn gluten feed	40.0
Supplement	7.5

Table 2. Finishing diet composition on a dry matter basis.

Ingredient	Percent of Diet
High-moisture corn	47.5
Wet corn gluten feed	40.0
Corn silage	5.0
Supplement	7.5

Table 3. Performance data for growing beef heifers fed morning vs. evening feeding.

Time	ADG(kg/d)	ADMI(kg/d)	G:F
AM	1.41	8.90	.1580
PM	1.44	9.05	.1595

Table 4. Performance data for finishing beef heifers fed morning vs. evening feeding.

Time	ADG(kg/d)	ADMI(kg/d)	G:F
AM	.662	8.67	.0767
PM	.739	8.82	.0836

COMPARISON OF CONTROL, GAINPRO, AND MONENSIN/TYLOSIN IN FINISHING DIETS CONTAINING WET CORN GLUTEN FEED

A. E. Wertz, L. L. Berger, and T. G. Nash

SUMMARY

Two hundred and forty yearling, crossbred steers were used to evaluate steer performance when supplementing 10-20 mg of bambermycin/hd/d, 250-270 mg/hd/d monensin plus 80-100 mg/hd/d tylosin or no additive to corn/wet corn gluten feed diets. Steers were gradually stepped-up to a final diet of 50% cracked corn, 30% wet corn gluten feed, 10% corn silage, 10% additive supplement. Feedlot performance and carcass characteristics data were collected for the steers and statistically analyzed. Average dry matter intake and average daily gain were not significantly affected by feed additive. However, steers supplemented bambermycin gained 5.6% faster than those supplemented monensin/tylosin when corn/wet corn gluten feed diets were fed. Feed efficiency was similar for both the bambermycin and monensin/tylosin supplemented steers. However, the bambermycin and monensin supplemented steers were both more efficient than the steers fed the non-additive supplement. Carcass merit was not affected by feed additive. Liver abscesses were decreased for steers supplemented monensin/tylosin relative to those steers supplemented bambermycin on fed the non-additive supplement. Supplementing bambermycin to corn/wet corn gluten feed finishing diets improved feed efficiency relative to non-additive supplemented steers.

INTRODUCTION

Cattle feeding is a complex business management system utilizing cattle and feed to produce a nutritious, palatable and wholesome food commodity. The profit or loss of cattle feeding is the amount received for the finished cattle minus the price paid for the feeder cattle as well as all cost incurred throughout the feeding period. There are many variables that regulate production decisions which ultimately affect profits. Profits are made or lost by the production decisions that directly affect daily live weight gain, cost of gain, feed conversion efficiency, and carcass composition.

Numerous studies have documented the benefits of monensin and lasalosisid ionophore administration during the grower, stocker, and finishing. These benefits come in the form of improved performance and a cheaper cost of gain. However, potential problems exist regarding reduced supplement or ration palatability and accidental consumption by monogastric species (specifically horses).

Hoechst-Roussel Agri-Vet Company is currently testing and marketing a inclusion-rate antibiotic that mediates ruminal changes similar to ionophores and yet is not an ionophore. As a result, this additive appears to have similar positive effects on rumen fermentation characteristics without the negative effects of reduced palatability or potential toxicity problems caused by ionophores. This antibiotic, bambermycin, has the trade name Gainpro. It is a member of a class of phosphorous-containing antibiotics formed by a group of gray-green streptomyces. Bambermycin

is predominantly effective against gram positive pathogenic bacteria and acts to inhibit the synthesis of the bacterial cell wall. Additionally, bambarmycin has been shown to not be absorbed by the host animal, and is rapidly biodegrade in the feces.

Gainpro seems to positively impact the rumen microbial population and environment to increase fiber and starch digestion. Research in the field has demonstrated that Gainpro will increase gains on pasture by an average of 15% over negative controls. The feedyard research has shown improvements of 3.9% in feed efficiency and 2.5% in average daily gain over negative controls.

Finishing cattle in feedyards is a very competitive business with relatively low profit margins. Feedyards are constantly looking for methods of reducing costs and increasing performance. Byproduct feed may be one opportunity to reduce feed costs in the future. With the rapid expansion of the corn wet milling industry to produce alcohol and high fructose corn syrup, supplies of byproducts are rapidly increasing. In 1994, approximately 1.7 billion bushels of corn were processed for the production of alcohol, syrups, or other food products. For each bushel of corn which is wet milled, 23 pounds of feed byproducts are produced.

In the past, over 85% of the corn gluten feed produced in this country has been exported. However, as a result of the GATT negotiation, corn gluten feed will loose most of its competitive advantage in the export markets such that more of it will be fed domestically. In fact, many new wet milling plants are not installing dryers, meaning that from day one of operation they are committed to marketing their product in the wet form to cattle feeders. To sell large quantities in a reasonable hauling distance, wet corn gluten feed will have to be priced competitively with corn on an energy basis. Approximately one half the energy in wet corn gluten feed results from the fiber. As a feed source, wet corn gluten feed has been shown to have an energy value similar to dry rolled corn. While wet corn gluten feed contains a large amount of fiber (41%) and a limited amount of starch (26%), the fiber fraction is highly digestible (87%). To get the most productive energy from wet corn gluten feed, the fiber must be digested efficiently. Previous research has shown that Gainpro increases fiber digestion and may therefore improve the utilization of diets containing wet corn gluten feed.

OBJECTIVE

The objective of this trial was to evaluate the feedlot performance of steers fed wet corn gluten feed based diets supplemented with no additive, Gainpro supplying 10-20 mg of bambarmycin per head per day, or a supplement supplying 250-270 mg monensin and 80-100 mg tylosin per head on a daily basis.

MATERIALS AND METHODS

Two hundred and sixty yearling steers with similar breeding, age, and nutritional background were purchased off grass pastures in the fall of 1995. Purchased cattle had not been implanted with any anabolic implant for 60 d prior to trial initiation nor fed a feedgrade antibiotic within 30 d of trial initiation. Upon arrival at the University of Illinois Beef Research Unit, the steers were immediately fed grass hay and .91 kg/hd of a corn, soybean meal, molasses supplement. The

cattle were gradually switched to a 50% corn silage 50% concentrate diet during the first week at the research facility. Cattle were vaccinated for IBR, PI3, 7-way clostridium, leptospirosis, hemophilus sumonus, BVD, and dewormed with a SafeguardTM drench. A preliminary weight was taken at the time of vaccination and all steers were implanted with 36 mg of Zeranol (RalgroTM). In addition, the steers were implanted with Revlor-STM at the first 28-d weigh period.

Two hundred and forty of the most uniform, healthy, steers were allotted to trial. Steers were allotted by weight, 8 hd/pen so that pen weights were similar across treatments. Pen assignments were made so that continental-crossbred steers and British-crossbred steers were equally represented across treatment pens. Two consecutive full weights were averaged to serve as initial weights for the trial. Final steer weights were calculated using the hot carcass weight (HCWT) divided by the average non-shrunk dressing percentage. In the case of excessive carcass trim, the final live weight of the steer was used as the final weight. Final weights were calculated based on carcass weights to reduce variation due to gut fill. Cattle were weighed at 28-d intervals throughout the 129 d trial to monitor their status and condition.

Initially, the steers were fed a basal diet containing 30% corn silage, 30% cracked corn, 30% wet corn gluten feed, and 10% vitamin-mineral-additive supplement containing the respective additive treatment. The corn silage was gradually replaced with cracked corn over the first two weeks of feeding until a final diet consisting of 50% cracked corn, 30% wet corn gluten feed, 10% corn silage, and 10% vitamin-mineral-additive supplement was reached. This diet was fed continuously throughout the remainder of the trial. Diets were formulated to supply 13.3% crude protein, .75% urea, .7% calcium, .45% phosphorous, .7% potassium and met or exceeded the NRC requirements for remaining nutrients. Diet samples were periodically analyzed for nutrient and additive content. Steers were bunk fed once daily at 9:00 a.m. Dry matter fed and feed refusals were monitored and recorded on a daily basis. Feed refusals were weighed, sampled and analyzed for dry matter content. Dry matter intakes were calculated by subtracting the unconsumed dry matter from the dry matter fed.

Four steers were treated for illness unrelated to experimental treatment. One steer recovered and was returned to its original pen as protocol dictated. The three remaining steers were removed from trial because of chronic illness or injury.

Steers were slaughtered at a commercial beef processing plant when 60 - 70% of the block was estimated to grade choice. All steers reached the compositional finish point at the same time and therefore all blocks were slaughtered at the same time. HCWT and liver abscess incidence (LAI) and Severity (LAS) were determined by a trained crew on the day of slaughter. Ribeye area (REA); 12th rib fat (RF); kidney, pelvic, and heart fat (KPH); and quality grade (QG) were collected by a trained crew after the carcass had hung in a refrigerated cooler at 4° C for 24 h. Yield grade (YG) was calculated using the equation $2.50 + 2.50(\text{inches RF}) + 0.20(\% \text{ KPH}) + 0.0038(\text{lb. HCWT}) - 0.32(\text{inches}^2 \text{ REA})$.

Performance data (ADG, ADMI, and G:F) as well as percent of a pen which graded choice (%CHOICE) and liver abscess incidence as a percent of the pen (%LA) were collected and

statistically analyzed on a pen basis. The remaining carcass characteristics (REA, KPH, RF, LAI, LAS, QG, and YG) were tabulated and statistically analyzed on an individual animal basis. All parameters were statistically analyzed using the General Linear Models of SAS. Upon statistical significance ($P < .05$) of the protected F-statistic, mean differences resulting from treatment were separated using the Least Squared Means methods of SAS.

RESULTS

Experimental design dictated a similar initial weight across treatments (339.80 ± 5.57 kg). Steers regardless of treatment exhibited exceptional gains, averaging $1.63 \pm .12$ kg/d over the 131 d trial. No significant difference in ADG or ADMI resulted from dietary treatment (Table 3). However, steers fed Gainpro gained 5.6% faster and consumed 5.6% more feed than those fed monensin. Feed efficiency (G:F) was improved ($p < .05$) by the addition of both the monensin/tylosin supplement and the bambermycin supplement to the wet corn gluten feed base finishing diet (.1666 and .1665 vs. .1576 respectively) (Table 3). Carcass merit was not affected by the addition of either bambermycin or monensin/tylosin to the wet corn gluten feed diet (Table 4). Liver abscesses incidence on an individual basis (LAI) was decreased ($p < .05$) by the addition of monensin/tylosin to the diet. However, LAI was unaffected by the addition of bambermycin to the diet. On a pen basis, liver abscesses (LA) tended ($p < .11$) to be lowered by the monensin/tylosin treatment (Table 4).

CONCLUSIONS

Supplementing bambermycin (Gainpro) to wet corn gluten feed based diets enhances the feed efficiency of finishing beef steers in comparison to non-additive supplemented diets. The improvement in feed efficiency is similar to that achieved by supplementing monensin/tylosin to the wet corn gluten feed diet. The 5.6% faster gains compared to monensin would be an advantage for feedlot operators. Additional, research is needed to determine if the enhancement in rate of gain is a consistent response from feeding bambermycin.

Table 1. Final basal diet composition.

Item	%DMB
Corn silage	10
WCGF ^a	30
Cracked corn	50
Supplement	10

^aWet corn gluten feed.

Table 2. Protein-growth-promoting additive supplement composition.

Ingredient	Bambermycin	Control	Monensin/tylosin
	% DMB		
Ground corn	64.27	64.34	69.05
Urea	6.96	6.96	7.50
Limestone	17.73	17.73	19.09
TMS + Se	2.79	2.79	3.00
Blood meal	.93	.93	1.00
Vit A D E	.10	.10	.10
Bambermycin	.075	----	----
Monensin	----	----	.156
Tylosin	----	----	.10

Table 3. Effects of ionophore supplementation and corn gluten feed finishing diets on steer performance.

Item	Ionophore			SEM
	Bambermycin	Control	Monensin	
Observations (pens)	10	10	10	
Initial wt. (kg) ^d	336.90	340.36	341.54	1.72
Final wt. (kg) ^c	559.29	548.50	552.09	5.59
ADG (kg/d)	1.70	1.59	1.61	.037
ADMI (kg/d)	10.21	10.09	9.66	.186
G:F	.1666 ^a	.1576 ^b	.1665 ^a	.002

^{a, b}Means within a row differ ($p < .05$) as a result of ionophore treatment.

^cEstimated final weight were calculated by dividing the final carcass weight by the average dressing percent to reduce variation due to fill.

^dInitial weights were the average of two consecutive day weights.

Table 4. Effects of ionophore supplementation and corn gluten feed finishing diets on beef carcass merit.

Item ^a	n	Ionophore			SEM
		Bambermycin	Control	Monensin	
HCWT (kg)	236	329.95	323.57	325.66	2.11
Dress (%)	236	59.21	58.93	59.26	.11
Rib fat (cm ²)	231	.95	.96	1.00	.02
KPH (%)	231	2.10	2.15	2.18	.04
QG ^b	231	10.13	10.35	10.24	.05
REA (cm ²)	227	83.16	81.51	82.80	.53
YG	227	2.50	2.54	2.54	.04
LAS	33	1.86	1.85	1.87	.15
LAI ^c	237	18.10	19.37	5.40	2.23
LA (%)	10	17.88	17.88	5.38	4.14
Choice (%)	10	84.07	92.46	83.89	4.41

^aHot Carcass Weight (HCWT), Dressing Percentage (DRESS) = HCWT/final live wt., Rib Fat between 12 th and 13 th rib, Kidney Pelvic and Heart fat (KPH), Quality Grade (QG), Ribeye Area (REA), Yield Grade (YG), Liver Abscess Severity (LAS) 1 = least severe and 3 = most severe, Liver Abscess Incidence (LAI) percentage by treatment based on individuals within a treatment, Liver Abscess as a percent of pen (LA), Percent of steers within a pen which graded choice (CHOICE).

^bSelect = 9, Low Choice = 10, Average Choice = 11, High Choice = 12, Prime = 13.

^cMean within a row differ ($P < .05$) as a result of ionophore treatment.

INFLUENCE OF GROWING DIET ENERGY SOURCE AND IONOPHORE ON SUBSEQUENT FINISHING PHASE PERFORMANCE OF STEERS FED FOUR LEVELS OF WET CORN GLUTEN FEED

A. E. Wertz, L. L. Berger, and T. G. Nash

SUMMARY

The addition of laidlomycin to high grain finishing diets has been documented to improve feedlot production. However, limited data exists as to the effect of laidlomycin supplementation on the performance of growing steers fed ad libitum roughage diets or limit-fed grain diets. This trial was initiated to compare the performance of steers fed control, laidlomycin, and monensin, supplemented ad libitum corn silage-wet corn gluten feed (CS-WCGF) diets to the performance of steers limit-fed high moisture corn-wet corn gluten feed (HMC-WCGF) diets supplemented with laidlomycin. One-hundred and forty-four crossbred beef steers were allotted by weight, six to a pen. Two consecutive full weights were taken at trial initiation and termination and intermediate weights were taken at 28 d intervals. Randomly assigned ionophore treatments were: no ionophore (CONT), 20g monensin/ton of diet (MON20), 5g laidlomycin/ton of diet (CATT5), and 10g laidlomycin/ton of diet (CATT10). Cattle on the remaining two treatments (REST25 and REST50) received laidlomycin at 10g/ton of diet and DMI was restricted to 85% of that for CATT10 steers. The REST25 and REST50 diets were composed primarily of HMC with 25% or 50% WCGF respectively. CATT5 and CATT10 steers gained similarly, however, the ADG of the CATT10 steers exceed that of the other steers. By experimental design, ADMI for REST25 and REST50 steers were less than the CATT10 steers. Restricting the ADMI reduced steer ADG. The improved feed efficiency (G:F) of the restricted intake steers reflects the substitution of HMC and WCGF for CS. The addition of laidlomycin to CS-WCGF diets improved the ADG and G:F of the steers.

INTRODUCTION

With the rapid expansion of the corn wet milling industry to produce alcohol and high fructose corn syrups, corn gluten feed supplies have increased rapidly. In 1994, approximately 1.7 billion bushels of corn were processed for the production of alcohol, syrups or other food products. In the past, over 85% of the corn gluten feed produced in this country has been exported. However, as a result of GATT and the changing programs in the EC countries, many experts believe gluten feed exports will decrease over time. In fact, some of the new wet milling plants are not putting in dryers, meaning that from day one of operation they are committed to marketing their byproducts in the wet form to cattle feeders and dairyman.

Corn silage based diets are commonly used as growing diets for feeder steers in the mid-western United States. Routinely, monensin is added to these diets to enhance the growth rate of steers and improve their feed efficiency. The efficacy of laidlomycin (Cattlyst) in high grain diets has been established. However, limited data exists comparing laidlomycin and monensin in corn silage based diets.

At times the relatively low price of corn has prompted many cattle feeders to consider feeding finishing diets at restricted intakes during the growing phase of feedlot production. This program has resulted in improved feed efficiencies and may reduce costs of gain. Little or no data is available comparing the performance of growing steers fed restricted intakes of laidlomycin-supplemented finishing diets to the performance of steers fed an ad libitum corn silage-wet corn gluten feed based diet.

OBJECTIVES

The objectives for the growing phase of this trial were to compare the performance of growing steers fed corn silage-wet corn gluten feed (CS-WCGF) based diets supplying 0, 5, or 10 g laidlomycin/ton of diet, to the performance of growing steers fed the same diet supplying 20 g monensin/ton of diet. Secondly, to compare the performance of growing steers fed laidlomycin-supplemented high moisture corn-wet corn gluten feed (HMC-WCGF) finishing diets at restricted intakes to the performance of growing steers fed an ad libitum laidlomycin-supplemented CS-WCGF diet. The objective of the finishing phase was to determine if percent of wet corn gluten feed (WCGF) in the finishing diet or the interaction of ionophore treatment and WCGF would affect feedlot performance or carcass merit. In addition, the effects of intake restriction were examined.

MATERIALS AND METHODS

Growing Phase. One hundred and forty-four beef steers were allotted by weight, six each to 24 pens. Pen allotments were assigned so that initial pen weights were similar across treatments. One of six treatments was assigned at random to each pen. All dietary treatments were balanced to meet or exceed NRC requirements for growing steers gaining 1.27 kg/d. Diet compositions are represented as a percent of the total diet on a dry matter basis (DMB) in Table 1 and in Table 2 the supplement compositions are represented as a percent of the total supplement on a DMB. Control steers (CONT) had ad libitum access to a basal diet of 25% wet corn gluten feed (WCGF), 70% corn silage (CS) and were fed a supplement, containing no ionophore, at 5% of the diet. The CATT5 and CATT10 steers received the same basal diet ad libitum but, were fed a supplement that supplied 5g or 10g laidlomycin/ton of diet respectively. The RUM20 steers also had ad libitum access to the basal diet and a supplement, fed at 5% of the diet, supplying 20g monensin/ton of diet. The ionophores were administered orally and fed continuously throughout the growing phase.

The REST25 steers were fed an initial diet of 25% WCGF, 40% CS, 30% high moisture corn (HMC), and 5% supplement supplying 10g laidlomycin/ton of diet. The percentage of HMC was gradually increased and the level of CS decreased over the first 28d of the growing phase. The steers were then maintained on the final diet composed of 25% WCGF, 10% CS, 60% HMC, and 5% supplement supplying 10g laidlomycin/ton of diet for the remainder of the phase. The REST25 steers were fed at a level equal to 85% of the dry matter intake (DMI) of the CATT10 steers. The restriction was implemented to achieve a gain similar to that of the CATT10 steers. A similar regime was used when feeding the REST50 steers. These steers were initially fed 50% WCGF, 40% CS, 5% HMC, and 5% supplement which supplied 10g laidlomycin/ton of diet.

The percentage of HMC was increased and the percentage of CS decreased over the first 28d period until a final diet composed of 50% WCGF, 10% CS, 35% HMC, 5% supplement supplying 10g laidlomycin/ton of diet was reached. Intake for the REST50 steers was restricted to 85% of the DMI for the CATT10 steers. All steers had ad libitum access to water. Dry matter intakes and refusals were monitored and recorded daily. Average dry matter intakes (ADMI) were calculated on a pen basis.

Two weights were taken on consecutive days at initiation and termination of the growing phase to minimize variation due to gut fill. The average of the two initial weights was used as starting weight for the growing phase. Likewise the two consecutive weights taken at the end of the growing phase were averaged and served as the final weight for the growing phase. In addition, intermediate weights were taken every 28 d throughout the 87 d growing phase.

Feedlot performance data were compiled for each pen. Data were statistically analyzed using the GLM procedures of SAS with pen as the experimental unit. Upon statistical significance ($P < .05$) of the protected F-test, differences resulting from treatment were separated using the Least Squared Means method of SAS. The effects 0, 5, or 10g laidlomycin/ton of diet on performance characteristics of the growing steers were compared to the effects in feedlot performance resulting from the addition of 20g monensin/ton of diet.

In addition, the performance of steers restricted in their intake of the higher-energy finishing diets during the growing phase was compared to the performance of steers with ad libitum access to the CS-WCGF based growing diet.

Finishing Phase. Pen allotments assigned for the growing phase of this trial were maintained throughout the finishing phase. The four levels of WCGF (25.0, 37.5, 50.0, 62.5) were assigned each to four pens so that every level of WCGF was represented within each ionophore block which existed in the growing phase. The steers were allowed ad libitum access to their respective diet daily. The steers in the restricted intake blocks of the growing phase were maintained on their respective level of WCGF (25 or 50%), but fed ad libitum. Diet compositions were balanced to meet or exceed NRC requirements and are reported as a percent of total diet on a DMB in Table 3 and in Table 4 the supplement composition is represented as a percent of the total supplement on a DMB. Feed intakes and refusals were recorded on a daily basis and water was provided ad libitum. ADMI was calculated based on pen intakes for the finishing phase.

Final weights for the growing phase served as the initial for the finishing phase. The steers were weighed every 28 d throughout the 119 d finishing phase to monitor the performance of the steers. The steers were fed to a compositional endpoint of approximately 0.4 inch external fat cover as determined by visual appraisal prior to shipment. Hot carcass weight (HCWT) and liver abscess (LA) data were collected at the time of slaughter. HCWT was divided by a constant dressing percentage of 62% to calculate the final empty body weights for the steers and average daily gains (ADG) were calculated using this weight as the final weight for the finishing phase. The carcasses were allowed to hang at -4°C for 24h prior to collection of the remaining carcass data. The remaining carcass characteristics were taken on the rail. For this reason, Chromatography paper was used to make an image of the longissimus muscle and grid measurements of the image were taken at a later time to determine ribeye area (REA). External fat cover was measured at the 12th

rib and quality grades (QG) were determined by a USDA grader at the processing plant. Yield grades (YG) were calculated using the data collected.

Feedlot performance data compiled for each pen were statistically analyzed using the GLM procedures of SAS with pen as the experimental unit. Growing ADG was used as a covariate in the analysis. However, the covariate and its interaction with WCGF were non-significant and were deleted from the model. Upon attaining statistical significance ($P < .05$) of the protected F-test, statistical trends were examined and differences resulting from treatment were separated using the Least Squared Means method of SAS.

Carcass data were statistically analyzed with each animal serving as an individual experimental unit. GLM procedures of SAS were used to generate the protected F-statistic and test for its significance. Growing ADG again was used as the covariate. The interaction of growing ADG and WCGF was removed due to non-significance. Upon attaining statistical significance ($P < .05$) of the protected F-test, trends were examined and differences resulting from treatment were separated using the Least Squared Means method of SAS.

Combined Phase Analysis. The growing and finishing phases were then combined to determine if carry-over effects resulted from treatment during the growing phase. Upon attaining statistical significance ($P < .05$) of the protected F-test, trends were examined and differences resulting from treatment were separated using the Least Squared Means method of SAS.

RESULTS

Growing Phase. Feedlot steer weights were similar across treatments at phase initiation (262.1 ± 4.18 kg) ($P > .10$). Termination weights were also similar (408.4 ± 6.63 kg) ($P > .10$). CATT10 (1.76 kg/d) steers gained faster ($P < .05$) than the CONT (1.65 kg/d), and the RUM20 (1.66 kg/d) steers (Table 5). The CATT5 (1.72 kg/d) steers were similar in their rate of gain to the CATT10 steers but tended ($P < .10$) to gain faster than the CONT steers. Neither the addition of laidlomycin or monensin to the CS-WCGF based diet affected the average dry matter intake (ADMI) of the steers. Feed efficiency for the RUM20 steers (.2057) was not different ($P > .10$) from the CONT (.1955), the CATT5 (.2165) or the CATT10 (.2125) steers. However, the CATT5 and CATT10 steers were more efficient in their gain than the CONT steers.

Experimental design dictated a lower ($P < .05$) average dry matter intake (ADMI) for the REST25 and the REST50 steers (Table 5). Restricting the dry matter intake (DMI) of growing steers receiving the finishing diet limited the average daily gain of the steers. CATT10 (1.76 kg/d) steers gained faster ($P < .05$) than the REST25 (1.68 kg/d) and the REST50 (1.62 kg/d) steers. In addition, the CATT5 steers gained faster ($p < .05$) than the REST50 steers, 1.72 kg/d vs. 1.62 kg/d respectively. Restricting DMI to accommodate a more moderate rate of gain improved ($P < .05$) the feed efficiency of the steers. The REST25 and REST50 steers were 12% more efficient in their gain than the CATT10 steers. Similarly, the REST25 and the REST50 steers gained 22% more efficiently than the CONT steers.

Finishing Phase. The steers weighed 408.4 ± 6.63 kg at the initiation of the finishing phase. Intake was not affected as a result of the percent of WCGF in the finishing diet. The steers consumed an average of 9.31 ± 0.58 kg of dry matter daily across treatments. Increasing the percent of WCGF in the finishing diet tended ($P < .10$) to linearly decrease the finishing ADG of the steers. Feedlot performance data and carcass data are reported in Table 6 and Table 7 respectively. Although the tendency did exist for ADG to decrease as the percent of WCGF was increased, the trend did not effect the finishing G:F. The average finishing G:F of the finishing steers was 0.1366 ± 0.01 across all treatments.

Although, restricted intake of the HMC-WCGF was limited to the growing phase the resulting improvement in G:F was carried over into the finishing phase. The restricted intake steers had improved feed efficiencies ($P < .05$) in comparison to the ad libitum intake steers ($0.1425 \pm .002$ vs. $0.1129 \pm .006$ respectively). In addition, the finishing ADG for the restricted intake steers ($1.30 \pm .02$) tended ($P < .10$) to be greater than the ADG of the ad libitum steers ($1.14 \pm .06$).

Carcass merit was not affected as a result of percent of WCGF in the finishing diet. The mean HCWT for the steers was 349.5 ± 27.76 kg. The average quality grade of the finishing steers was 2.33 ± 0.68 (1= USDA Prime, 2= USDA Choice, 3= USDA Select) and 75% of the carcasses graded USDA choice. Average yield grade was 2.31 ± 0.59 across all treatments for the finishing steers having an overall average REA of 90.63 ± 9.02 cm². In addition, the number and severity of liver abscesses (0.47 ± 0.97) and external fat cover (0.89 ± 0.28 cm) were similar for all steers regardless of percentage of WCGF in the finishing diet (Table 7).

Combined Phases. The growing and finishing phases of beef production often occur on the same farm for corn belt cattle feeders. For this reason, the two phases of this trial were combined and the data generated examined to attain an indication of the effects these growing and finishing phase treatments had as a management regime. There was no ionophore by WCGF interaction and therefore was deleted from the model. Data were reported both from the aspect of growing phase carry-over effect on finishing feedlot performance and from the point of effects of percent WCGF and intake restriction on overall feedlot performance. Data for the combined trial appear in Table 8 and Table 9. The effect of ionophore treatment in the growing phase did not have a carry-over effect on feedlot performance in the finishing phase. The steers consumed an average of 8.57 ± 0.46 kg of dry matter on a daily basis and had a mean ADG of 1.43 ± 0.06 kg/d throughout the duration of the trial. Gain per unit of feed for the steers during the trial was 0.1674 ± 0.01 . The percentage of WCGF in the finishing diet did not have a significant effect on the feedlot performance of the steers for the combined-phases trial.

The CATT10 steers having restricted intakes of the HMC-WCGF diet during the growing phase had lower ($P < .05$) ADMI than did the CATT10 steers with ad libitum access to the CS-WCGF diet (Table 10). The lower ADMI was the result of experimental design of the growing phase. Although not significantly different, the ADG of the restricted steers ($1.45 \pm .02$ kg/d) throughout the duration of the trial was numerically greater than the ADG of the ad libitum fed steers ($1.39 \pm .04$ kg/d). The lower ADMI in combination with the numerically higher ADG of the restricted intake steers tended ($P < .08$) to improve the feed efficiency of the restricted intake steers. The steers receiving HMC-WCGF diets supplemented with 10g laidlomycin/ton of diet

at restricted intakes during the growing phase and an ad libitum HMC-WCGF diet throughout the finishing phase were 18% more efficient in their gain than the steers having ad libitum CS-WCGF supplemented with 10g laidlomycin/ton of diet in the growing phase and ad libitum HMC-WCGF in the finishing phase.

CONCLUSIONS

Growing Phase. The inclusion of 10g laidlomycin/ton diet improved the ADG of steers with ad libitum access to CS-WCGF diets. In addition, the inclusion of both 5g and 10g laidlomycin/ton of CS-WCGF based diet improved the feed efficiency of the growing feeder steers. Restricting the DMI of growing steers fed a HMC-WCGF finishing diet limited their rate of growth but improved their feed efficiency by 12% in comparison to steers receiving the ad libitum CS-WCGF diet supplemented with 10g of laidlomycin/ton.

Finishing Phase. The interaction of WCGF and ionophore was not significant. The percentage of WCGF in the finishing diet did not appear to have an effect on the finishing ADMI, finishing G:F nor carcass merit, provided NRC requirements for finishing steers were met. The finishing ADG tended to increase linearly as percent WCGF was decreased in the finishing diet. However, the increase in finishing ADG was not marked by an improvement in finishing G:F.

Combined Phases. Restricting the intake of HMC-WCGF diets, which supply 10g laidlomycin/ton of diet, during the growing phase followed by a HMC-WCGF finishing diet improved the feed efficiency of the feedlot steers. The improvement in efficiency was largely a result of restricted intakes in the growing phase accompanied by a numerically improved ADG in the finishing phase.

IMPLICATIONS

HMC-WCGF finishing diets fed at restricted intakes can replace ad libitum corn silage-WCGF during the growing phase of feedlot production to improve feed efficiency without compromising ADG. Feeding up to 50% WCGF in the finishing phase resulted in excellent performance.

Table 1. Diet composition for growing steers supplemented Cattlyst at 5g or 10g/ton compared to growing steers supplemented 20g/ton Rumensin.

Ingredient ^a	Dietary Treatment ^b					
	Control	CATT5	CATT10	RUM20	REST25	REST50
Corn silage	70	70	70	70	10	10
WCGF	25	25	25	25	25	50
HMC	----	----	----	----	60	35
Supp# 473 ^c	5.0	2.5	----	----	----	----
Supp# 471 ^c	----	2.5	5.0	----	5.0	5.0
Supp# 472 ^c	----	----	----	5.0	----	----

^aDiet components represent a percentage of the total diet on a dry matter basis.

^bControl, no ionophore; CATT5, Cattlyst 5g/ton diet; CATT10, Cattlyst 10g/ton diet; RUM20, Rumensin 20g/ton diet; REST25, 25% WCGF diet restricted to 85% of CATT10 intake; REST50, 50% WCGF diet restricted to 85% of CATT10 intake.

^cSupplement #471 contained Cattlyst, supplement # 472 contained Rumensin and Supplement # 473 was the Control.

Table 2. Supplement composition for growing steers receiving 5g or 10g/ton Cattlyst, 20g/ton Rumensin, or non-medicated Control.

Ingredient ^a	Supplement		
	Cattlyst	Rumensin	Control
Ground corn	46.67	46.325	46.60
Blood meal	25.60	25.60	25.60
Urea	5.00	5.00	5.00
Limestone	16.70	16.70	16.70
TMS	6.00	6.00	6.00
Cattlyst (50g/lb)	.22	----	----
Rumensin (80g/lb)	----	.275	----
Vit A D E	.10	.10	.10

^aSupplement components represent a percentage of the total Supplement on a dry matter basis.

Table 3. Diet composition for finishing steers fed increasing increments of wet corn gluten feed.

Ingredient ^a	% Wet Corn Gluten Feed			
	25.0	37.5	50.0	62.5
High moisture corn	57.0	46.0	35.25	24.5
Supplement	10.0	10.0	10.0	10.0
Corn silage	8.0	6.0	4.0	2.0
Limestone	----	0.5	0.75	1.0

^aDiet components represent a percentage of the total diet on a dry matter basis.

Table 4. Supplement composition for finishing steers fed increasing increments of wet corn gluten feed.

Ingredient ^a	% of Supplement (DMB)
Corn	70.76
Limestone	10.55
Urea	7.25
Blood meal	4.65
Swine TMS	2.08
Magnesium oxide	1.85
Potassium chloride	1.85
Monensin-80	0.14
Vitamin ADEK	0.10
Copper sulfate acidified	0.05

^aSupplement components represent a percentage of the total supplement on a dry matter basis.

Table 5. Feedlot performance of growing steers receiving 0g, 5g, or 10g/ton Cattlyst compared to growing steers fed 20g/ton Rumensin.

Treatment	ADG(kg/d)	ADMI (kg/d)	Gain:Feed (kg/kg)
Control	1.65 ^{b, c}	8.47 ^a	.1955 ^a
Cattlyst 5g	1.72 ^{a, c}	7.98 ^a	.2165 ^b
Cattlyst 10g	1.76 ^a	8.27 ^a	.2125 ^b
Restricted 25	1.68 ^{b, c}	7.07 ^b	.2374 ^c
Restricted 50	1.62 ^{b, c}	7.09 ^b	.2283 ^c
Rumensin 20	1.66 ^{b, c}	8.08 ^a	.2057 ^{a, b}

^{a,b,c}Means within a column having different superscript letters differ as a result of treatment ($P < .05$).

Table 6. Feedlot performance of finishing steers receiving increasing increments of wet corn gluten feed.

%WCGF(DMB)	ADMI (kg/d)	ADG (kg/d) ^a	Gain:Feed
25.0	9.21	1.30	0.1413
37.5	9.65	1.26	0.1303
50.0	8.99	1.26	0.1405
62.5	8.91	1.15	0.1290

^aLinear ($P < .10$).

Table 7. Carcass data for finishing steers fed increasing increments of wet corn gluten feed.

% WCGF	HCWT (kg/d)	Liver ^a Abscesses	Quality ^b Grade	Yield Grade	Ribeye Area (cm ²)	Back Fat (cm)
25.0	356.47	0.25	2.26	2.39	91.14	0.94
50.0	345.98	0.61	2.33	2.15	91.97	0.81
75.0	350.49	0.34	2.27	2.37	89.79	0.89
62.5	341.45	0.88	2.58	2.23	90.40	0.86

^aThe liver abscess data: 0 = no abscess; 1 = 1 small abscess, liver condemned; 2 = 1 large or 2 or more small abscesses, liver condemned; 3 = 2 or more large liver abscesses, liver condemned.

^b1 = USDA Prime, 2 = USDA Choice, 3 = USDA Select.

Table 8. Combined feedlot performance for steers receiving ionophore treatments during the growing phase and increasing increments of wet corn gluten feed during the finishing phase.^a

Ionophore	ADMI (kg/d)	ADG (kg/d)	Gain:Feed (kg/kg)
Control	8.95	1.41	0.1582
Cattlyst 5g	8.64	1.45	0.1688
Cattlyst 10g	8.70	1.41	0.1619
Restricted 25	8.59	1.50	0.1753
Restricted 50	8.17	1.40	0.1722
Rumensin 20g	8.57	1.40	0.1636

^aNo interaction occurred between ionophore and level of WCGF. Therefore respective carry-over effects of the ionophore and the effects of level of WCGF preceded by ionophore treatment in the growing phase are reported separately.

Table 9. Combined feedlot performance for steers fed increasing increments of wet corn gluten feed during the finishing phase preceded by ionophore treatment in the growing phase.^a

% WCGF	ADMI (kg/d)	ADG (kg/d)	Gain:Feed (kg/kg)
25.0	8.69	1.46	0.1678
37.5	8.86	1.45	0.1647
50.0	8.30	1.40	0.1697
62.5	8.56	1.40	0.1644

^aNo interaction occurred between ionophore and level of WCGF. Therefore respective carry-over effects of the ionophore and the effects of level of WCGF preceded by ionophore treatment in the growing phase are reported separately.

Table 10. Growing-finishing performance of feedlot steers receiving ad libitum corn silage-wet corn gluten feed or restricted high moisture corn-wet corn gluten feed during the growing phase and ad libitum high moisture corn-corn silage during the finishing phase.

Growing Phase			
Intake	ADMI (kg/d)	ADG (kg/d)	G:F (kg/kg)
Ad libitum	9.25 ^a	1.39	.1491 ^c
Restricted	8.27 ^b	1.45	.1756 ^d

^{a,b}Differ (P < .05).
^{c,d}Differ (P < .08).

EFFECTS OF SUPPLEMENTAL CARNITINE ON THE PERFORMANCE OF FEEDLOT HEIFERS FED MEDIUM ENERGY GROWING DIETS

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SUMMARY

Carnitine has been reported to improve feed efficiency in beef heifers receiving high roughage diets. However, limited research exists as to the optimal level of supplemental carnitine. Therefore, this trial was initiated to determine the optimal dosage of supplemental carnitine for feedlot heifers fed higher roughage diets. One-hundred and ninety-two crossbred heifers were allotted, eight each to 24 treatment pens. Supplemental carnitine dosages of 0, 0.3, 0.6, 0.9, 1.2, or 1.5 g/hd/d were assigned at random to each of four pens. The cattle were fed a medium energy basal diet of 52.5% corn silage, 40.0% wet corn gluten feed, and 7.5% supplement. The supplemental carnitine was provided in a 0.23 kg/hd/d ground shelled corn-MGA carrier. The diet was provided ad libitum excluding the days of trial initiation and termination where intake was restricted to reduce weight variation due to fill. Weights were taken at 28 d intervals from trial initiation to trial termination. The trial lasted for 102 d. Data collected were analyzed by analysis of variance procedures for a complete randomized block (CRB) design according to the GLM procedures for SAS (1985). Differences in treatment means resulting from effects of diet were separated using the Least Square Means method and contrasts were run to establish trends. Initial and final pen weights did not differ between treatments ($P > .10$). Average daily gain (ADG) for all cattle on treatment was $1.42 \pm .064$ kg/d and did not differ as a result of supplemental carnitine dosage. Average dry matter intake (ADMI) tended ($P < .08$) to behave in a quadratic manner. Heifers receiving carnitine at 0.3 g/hd/d had the highest ADMI while heifers receiving supplemental carnitine at 1.5 g/hd/d had the lowest ADMI. Dry matter consumption as a percent of body weight (DMIPBW) was similar for all heifers receiving 1.2 g/hd/d or less supplemental carnitine. However, heifers receiving 1.5 g/hd/d supplemental carnitine had significantly lower ($P < .004$) DMIPBW. Feed efficiency (G:F) was not significantly affected by supplemental carnitine dosage. However, heifers supplemented carnitine at 1.5 g/hd/d were 7.6% more efficient in their gain over control heifers. These results indicate that supplemental carnitine at a level of 1.5 g/hd/d reduced ADMI which numerically resulted in improved feed efficiency for feedlot heifers receiving a medium energy, high roughage diet.

INTRODUCTION

Newton and Burtle (1991) concluded carnitine should benefit agriculturally important animals by improving their performance or well-being under specific conditions. Numerous conditions are believed to influence the effects of supplemental carnitine. Carnitine levels in the blood, milk and muscle of ruminants has been found to decrease during extended exposure to cold weather (Newton and Burtle, 1991). In addition to environment, the sex of the animal may impact the responsiveness of that animal to carnitine supplementation. Newton and Burtle (1991) found that carnitine supplemented female pigs of light to medium weights, grew significantly faster and had improved feed efficiencies when compared to male castrate pigs supplemented with the same level of carnitine. Similar results have been sighted in cattle. Feedlot heifers fed ad libitum hay and

2.5 kg of corn-soybean meal supplement containing 0.6 or 1.2 g/hd/d of carnitine had improved gains and feed efficiencies of 26.7% and 25.3%, respectively (Hill and Newton, 1993). However, no advantage in feed efficiency was observed for feedlot steers fed the same hay and supplement with the same dosage of carnitine (Hill and Newton, 1993).

Carnitine facilitates the transport of long chain fatty acids across inner mitochondrial membrane in the liver (Stryer, 1988). Carnitine is believed to relieve “acetyl pressure” on the CoA system (the reduction in free CoA which results from high levels of acetate) (Newton and Burtle, 1991).

Carnitine has been reported to affect digestive and metabolic functions in the ruminant animal. La Count et al. (1995) reported improved digestible and metabolizable energy from diets supplemented with carnitine. Similarly, La Count et al. (1995) found a tendency for carnitine supplementation to improve the digestibility of neutral detergent fiber, and cellulose which may have attributed to the overall improvement in digestible energy. However, the increased digestible and metabolizable energy levels did not increase milk energy secretion. It was therefore concluded that the resulting increase was attributed to body storage.

Supplemental carnitine tended to increase the concentration of total volatile fatty acids (VFA) produced in the rumen which suggested enhanced rumen fermentation. In addition, supplemental carnitine tended to decrease the acetate to propionate ratio in the rumen (La Count et al., 1995).

Carnitine supplemented at levels of 0.6 and 1.2 g/hd/d has been reported to improve the feed efficiency of beef heifers fed moderate energy, high roughage diets. The enhancement in rumen fermentation and increased digestibility of diets supplemented with carnitine provide a biological explanation for the improved feed efficiency in ruminants. However, limited data exists as to optimal dosage of supplemental carnitine. Therefore this trial was designed to determine the optimal dosage of carnitine for feedlot heifers fed moderate energy, high roughage growing diets.

MATERIALS AND METHODS

One hundred and ninety-two crossbred beef heifers were allotted by weight, eight each to 24 pens. Initial weights did not differ (289.89 ± 2.77 kg) across treatment pens. The cattle were withheld from feed 12 h prior to the initial weigh date and were restricted to 75% of the lowest consuming pen the feeding prior to the final weigh date. These measures were taken to minimize error due to variation in fill. Intermediate weights were taken at 28 d intervals. Heifers were maintained on treatment for 102 d.

Dietary carnitine doses of 0, 0.3, 0.6, 0.9, 1.2, and 1.5 g/hd/d were randomly assigned each to four pens. A medium energy basal diet composed of 52.5% corn silage, 40.0% wet corn gluten feed, and 7.5% supplement was fed daily and the carnitine dosage was provided in a 0.23 kg/hd/d ground shelled corn-MGA carrier (Table 1 and 2). Feed was provided ad libitum excluding the days of trial initiation and termination. Dry matter intakes were monitored daily and adjustments were made accordingly.

Data collected were analyzed by analysis of variance procedures for a complete randomized block (CRB) design according to the General Linear Models (GLM) procedures for SAS (1985). Model sums of squares for the CRB included treatment effects. Differences in treatment means resulting from effects of diet were separated using the Least Square Means method and contrasts were run to establish trends.

RESULTS AND DISCUSSION

The crossbred beef heifers assigned to treatment of varying levels of supplemental carnitine had similar initial weights (289.94 ± 2.64 kg). The 28 d weights for heifers fed varying levels of supplemental carnitine were not different having a mean of 352.25 ± 7.28 kg. Performance data at 28 d of treatment are reported in Table 3. The mean average daily gain (ADG) for the treatment heifers was $2.23 \pm .22$ kg/d and did not significantly differ as a result of supplemental carnitine level. Similarly, variation in the level of supplemental carnitine did not affect efficiency of gain (G:F) at 28 d of treatment ($.291 \pm .018$). Fill differences between day 1 and 28 account for the high gains and feed efficiency. Supplemental carnitine level did, however, influence average dry matter intake (ADMI) of the treatment heifers at 28 d of supplementation. ADMI behaved in a quadratic manner ($P < .05$). Control heifers, receiving no supplemental carnitine, averaged $7.10 \pm .17$ kg/d of dry matter intake over the 28 d period. This was lower ($P < .05$) than the heifers receiving additional increments of supplemental carnitine. ADMI appears to increase with the addition of supplemental carnitine at a level of 0.3 g/hd/d. However, additional increments of supplemental carnitine above the 0.3 g/hd/d level did not cause ADMI to increase above that seen for heifers receiving supplemental carnitine at 0.3 g/hd/d. As a percent of body weight, dry matter intake behaved in quadratic manner ($P < .05$) as well. Suggesting the increase in ADMI resulted in an increase in gain over the 28 d period.

Performance data for beef heifers receiving supplemental carnitine for 54 d are reported in Table 3. The mean weight of treatment heifers (388.19 ± 7.82 kg) at 54 d of treatment did not differ as a result of supplemental carnitine dose. The treatment heifers averaged $1.82 \pm .13$ kg/d gain over the 54 d period. No difference in ADG or Gain:Feed was observed for heifers fed various levels of carnitine. Similarly, differences in G:F did not result as an effect of variation in supplemental carnitine level. ADMI was, as at 28 d of treatment, affected quadratically ($P < .05$) by level of supplemental carnitine. Heifers supplemented with carnitine at a level of 0.3, 0.6, and 1.2 g/hd/d had higher ($P < .05$) ADMI than control heifers. In addition, heifers receiving 0.3 g/hd/d had higher ($P < .05$) ADMI than heifers receiving carnitine at the 0.9 or 1.5 g/hd/d level. Similar to ADMI at 54 d of treatment, DMIPBW at 54 d of treatment also behaved in a quadratic manner ($P < .05$) and was higher for heifers supplemented with 0.3, 0.6, or 1.2 g/hd/d carnitine than for control heifers.

Data resulting for the entire 82 d trial are reported in Table 3. Initial pen weights (289.89 ± 2.77 kg) and final pen weights (436.65 ± 7.35 kg) did not differ significantly across treatments ($P > .10$). The mean average daily gain (ADG) for all treatment heifers was $1.42 \pm .064$ kg/d and did not differ significantly as a result of dietary carnitine dosage.

However, average dry matter intake (ADMI) was significantly affected by treatment ($P < .0002$) and tend ($P < .08$) to behave in a quadratic manner (Figure 1). Heifers supplemented carnitine at a level of 0.3 g/hd/d consumed 9.35 kg/hd/d of dry matter. These heifers had significantly higher ($P < .01$) ADMI than all other treatment heifers. In contrast, heifers supplemented with carnitine at 1.5 g/hd/d consumed significantly less ($P < .01$) dry matter on a daily basis than did all other treatment heifers (8.63 kg/hd/d). Dry matter intake as a percent of body weight (DMIPBW) was significantly affected by supplemental carnitine ($P < .0002$) and behaved in a quadratic manner ($P < .03$). DMIPBW was lower ($P < .004$) for heifers supplemented carnitine at 1.5 g/hd/d than for heifers supplemented carnitine at 1.2 g/hd/d or less. Heifers receiving carnitine at a level of 1.5 g/hd/d consumed 2.36% of their body weight in dry matter, while heifers consuming carnitine at 1.2 g/hd/d or less consumed an average of $2.49 \pm .04\%$ of their body weight in dry matter.

The model for the feed efficiency (G:F) was not significant. However, control heifers were least efficient in their gain while heifers supplemented carnitine at 1.5 g/hd/d gained most efficiently. Heifers receiving 1.5 g/hd/d supplemental carnitine were 7.6% more efficient in their gain than control heifers.

The addition of carnitine in the diets of growing feedlot heifers did not appear to influence ADG. However, carnitine supplemented at a level of 0.3 g/hd/d increased ADMI. Additional increments of supplemental carnitine, to a level of 1.5 g/hd/d, appeared to reduce ADMI in growing feedlot heifers. Furthermore, carnitine at a supplemental level of 1.5 g/hd/d numerically improved the feed efficiency of growing feedlot heifers fed higher roughage, moderate energy growing diets.

REFERENCES

- La Count, D. W., J. K. Drackley, D.J. Weigel. 1995. Responses of dairy cows during early lactation to ruminal or abomasal administration of L-carnitine. *J. Dairy Sci.* 78:1824.
- Hill, G.M. and G.L. Newton. Carnitine supplementation effects on wean cattle growth and ruminal volatile fatty acid production. Final Report. 1993.
- Newton, G.L. and G.J. Burtle. Carnitine in food animal production. In *Current Concepts in Carnitine Research*. ed. A.L. Carter. CRC press, Boca Raton FL. 1991.
- SAS. 1985. SAS User's guide: Statistics. SAS inst. Inc., Cary NC.
- Stryer, L. *Biochemistry* 3rd. ed. W.H. Freeman and Company, New York. 1988.

Table 1. Carnitine trial -- Basal diet.

Ingredient	% of Diet
Corn silage	52.5
Wet corn gluten feed	40.0
Supplement	7.5

Table 2. Carnitine trial -- Supplement composition.

Ingredient	% of Supplement
Ground-shelled corn	74.25
Limestone	16.00
Blood meal	5.50
T.M. salts + Se	3.70
Rumensin 80	.25
A D E vitamin premix	.30

Table 3. Performance of beef heifers fed supplemental carnitine.

Supplemental Carnitine (g/hd/d)	ADG (kg/d)	ADMI (kg/d)	DMIPBW (%)	G:F
28 d Performance ^a				
0.0	2.10	7.10	2.22	.2973
0.3	2.40	8.17	2.53	.2945
0.6	2.18	8.02	2.52	.2920
0.9	2.09	7.95	2.48	.2813
1.2	2.29	8.13	2.54	.2865
1.5	2.29	8.09	2.50	.2940
54 d Performance ^b				
0.0	1.72	8.40	2.49	.2052
0.3	1.94	9.19	2.68	.2115
0.6	1.81	8.89	2.64	.2033
0.9	1.77	8.72	2.57	.2028
1.2	1.83	8.92	2.64	.2053
1.5	1.85	8.59	2.52	.2153
82 d Performance ^b				
0.0	1.61	8.88	2.49	.1812
0.3	1.61	9.47	2.66	.1704
0.6	1.63	9.08	2.56	.1793
0.9	1.57	9.00	2.53	.1747
1.2	1.66	9.18	2.57	.1812
1.5	1.62	8.69	2.43	.1862

^aADMI linear ($P < .05$) at 28 d.

^bADMI Quadratic ($P < .05$) at 54 d and 82 d.

BEEF PRODUCTION SYSTEMS COMPARING EARLY WEANING TO NORMAL WEANING WITH OR WITHOUT CREEP FEEDING FOR BEEF STEERS

S. E. Myers, D. B. Faulkner, F. A. Ireland, and D. F. Parrett

SUMMARY

A two-year study was conducted to determine the effects of weaning management systems for beef production. Cow-calf pairs were randomly assigned to one of three treatments, where the steer calves were: 1) weaned at 150 d of age and placed on a finishing diet (EW), 2) supplemented with grain from 150 to 205 d of age on pasture while nursing their dams and then placed on a finishing diet (NWC), and 3) on pasture from 150 to 205 d of age while nursing their dams and then placed on a finishing diet (NW). In year two, potential breed differences were evaluated using steers of three different breed types: 1) Angus \times Hereford (BRI), 2) Simmental crossbred (CON), and 3) Wagyu crossbred (WAG). In year one, EW steers had higher ADG than NWC and NW steers (1.44 vs 0.72 kg/d, $P = .0001$), and NWC steers had higher ADG than NW steers (0.86 vs 0.62 kg/d, $P = .02$) prior to 205 d. In the feedlot, EW steers had lower intakes (7.70 vs 8.16 kg/d, $P = .01$) and better feed conversions (.170 vs .153, $P = .002$) compared to NWC and NW steers. Marbling score was improved for EW steers compared to NWC and NW steers (1198 vs 1132, $P = .003$). In year two, EW steers had higher gains ($P = .0006$) during the entire study compared to NWC and NW steers, and NWC steers had higher gains ($P = .003$) than NW steers. EW steers had lower intakes (7.29 vs 7.68 kg/d, $P = .0008$) and better feed conversions (.160 vs .141, $P = .0001$) compared to NWC and NW steers. CON steers were heavier at slaughter than BRI steers ($P = .01$) and BRI steers were heavier than WAG steers ($P = .0004$). EW improved percent grading average choice or higher by 28%. BRI steers improved percent grading average choice or higher by 18% over CON steers, and improved percent grading average choice or higher by 25%. Cows with EW steers had higher ADG than cows with NWC and NW steers (0.38 vs -0.15 kg/d, $P = .0001$) prior to 205 d. Cows with EW steers gained body condition score (BCS 0.23 vs -0.11, $P = .0008$), while cows with NWC steers lost BCS and cows with NW steers did not change. EW improved feed efficiency and quality grades.

INTRODUCTION

In today's value-based marketing system, the competitive ability of the beef industry could be enhanced by raising cattle with a higher and more consistent quality end-product. Results of two separate National Beef Quality Audits this decade conclude the beef industry is falling short in meeting the demands of quality. In 1991, 55% of the carcasses graded Choice or Prime, but in 1995, the percentage had fallen to 48%, with less than 1% of the carcasses evaluated obtaining Prime quality. At the 1994 National Beef Tenderness Conference, researchers pointed out that one out of every four steaks is less than desirable in tenderness and palatability, and that every tough carcass affects as many as 542 consumers. The underlying conclusion was that consumers want high quality beef and the producer must be able to produce it efficiently. This study was designed to determine the effects of weaning management systems on 1) steer performance and carcass traits, 2) breed, and 3) cow performance, body condition score, and pregnancy rates.

MATERIALS AND METHODS

Steers and Diets. The experiment was conducted at the Dixon Springs Agricultural Center located near Simpson, IL. Steers were born from January-April and nursed their dams while grazing tall fescue (*Festuca arundinacea* Schreb.) - red clover (*Trifolium pratense* L.) pastures until mid-July when they were randomly assigned to one of three treatments where the steer calves were: 1) weaned at 150 d of age and placed on a finishing diet (EW), 2) supplemented with grain from 150 to 205 d of age on pasture while nursing their dams and then placed on a finishing diet (NWC), and 3) on pasture from 150 to 205 d of age while nursing their dams and then placed on a finishing diet (NW). In year 1, 84 Angus \times Hereford crossbred steers (144 ± 2 kg) were utilized. In year 2, 83 Angus \times Hereford (BRI, 151 ± 4 kg), 40 Simmental crossbred (CON, 160 ± 4 kg) and 44 Wagyu crossbred (WAG, 146 ± 4 kg) steers were utilized to evaluate potential breed differences. On d 150 and 205, all steers were weighed and measured at the hip and dams were weighed and assigned a body condition score (BCS; 1 to 9 scale). At 205 d, dams were palpated to determine pregnancy rates.

Steers on the NWC treatment had ad libitum access to ground corn for 55 d. Beginning at the time of weaning, steers were fed a grain diet ad libitum consisting of 64.25% cracked corn, 3.60% soybean meal, and 30.00% hay. Chopped hay, was removed stepwise from the finishing diet, and steers were adapted to their final diet within 44 d. Steers had ad libitum access to the high-concentrate diet for the remaining feeding period. Diet compositions are shown in Table 1.

One calf died during year one for reasons unrelated to treatment. Eight calves were lost in year two due to unusually high temperatures during the summer months. No other health or management problems were encountered.

All steers were implanted with Ralgro (Mallinckrodt Veterinary Inc., Mundelein, IL) and Revalor-S[®] (Hoechst-Roussel, Somerville, NJ) at seven and 11 months, respectively. Weights were recorded at the beginning and end of the finishing period. Daily gain, feed intake, and efficiency were calculated. Feed intakes are expressed as a daily average over the entire feeding period on a pen basis. In year one, two slaughter groups were used to slaughter steers between 0.8 and 1.4 cm of external fat thickness (1.1 cm average). In year two, four slaughter groups were used to slaughter steers between 0.8 and 1.4 cm of external fat thickness (1.1 cm average).

Carcass Characteristics. Steers were slaughtered at a commercial packing plant and hot carcass weights were obtained. After carcasses were chilled for 24 h, the following measurements were obtained by trained University of Illinois personnel: 1) longissimus muscle area taken by direct grid reading of the longissimus muscle at the 12th rib; 2) subcutaneous fat over the longissimus muscle at the 12th rib; 3) kidney, pelvic, and heart fat was estimated as a percentage of carcass weight; and 4) marbling score (USDA, 1975). Carcass measurements were used to calculate quality and yield grades. No attempt was made to evaluate maturity of the carcasses.

Statistical Analysis. Feedlot performance and carcass characteristics were analyzed as a completely randomized design experiment (Steel and Torrie, 1980) using the GLM procedure of SAS (1985). In year two, treatments were arranged as a 3 \times 3 factorial. Pen was the experimental

unit for the performance data and steer was the experimental unit for the carcass data. Treatment means were compared (orthogonal contrasts; Steel and Torrie, 1980) by the following contrasts: 1) treatment 1 vs 2 and 3 (EW vs NWC and NW), and 2) treatment 2 vs 3 (NWC vs NW). External fat thickness at slaughter was used as a covariate for analysis of performance and carcass traits. Cow was the experimental unit for the cow performance data.

RESULTS

Effect of Early Weaning on Calf Performance. Steer performance traits in year one are presented in Table 2. No differences ($P > .17$) were observed between treatments for initial and slaughter weights. Slaughter weights were calculated by dividing the hot carcass weight by 61 percent. Steers on EW had higher ADG than NWC and NW steers (1.44 vs 0.72 kg/d, $P = .0001$), and NWC steers had higher ADG than NW steers (0.86 vs 0.62 kg/d, $P = .02$) prior to 205 d. Steers that were NWC and NW had more rapid ADG than EW steers (1.38 vs 1.28 kg/d, $P = .002$) after 205 d. Compared with NWC and NW, EW improved ADG throughout the duration of the experiment (1.31 vs. 1.25 kg/d, $P = .01$).

In the feedlot, EW steers had lower intakes (7.70 vs 8.16 kg/d, $P = .01$) and better feed conversions (.170 vs .153, $P = .002$) compared to NWC and NW steers. EW steers consumed 180 kg more total feed than the NWC steers, and 305 kg more total feed than the NW steers. NWC steers consumed 125 kg more total feed than NW steers during the creep and feedlot phases.

Carcass traits for year one are presented in Table 3. EW steers tended ($P = .11$) to have heavier carcass weights, thus indicating the EW does not result in lighter weight cattle at slaughter. Longissimus muscle area was not enhanced ($P > .65$) by treatment. Additionally, no differences ($P > .18$) were observed when longissimus muscle area is expressed as square centimeters per kilogram of carcass weight. There were no differences ($P > .07$) associated with USDA yield grades. Fifty-nine percent of the steers graded USDA yield grade 2.9 or better.

Significant differences in marbling scores were observed. Marbling score was improved for EW compared to NWC and NW (1198 vs 1132, $P = .003$). EW improved percent grading average choice or higher by 27%. In year one, EW improved overall gain, feed efficiency and quality grades.

There were significant treatment \times breed interactions ($P < .05$) for performance traits in year two. The effect of treatment and breed on performance traits is shown in Table 4. As in year one, slaughter weights were calculated by dividing the hot carcass weight by 61 percent. EW steers were heavier at slaughter compared to NWC and NW steers ($P = .004$), and there were no differences ($P > .22$) between NWC and NW steers. CON steers were heavier at slaughter than BRI steers ($P = .01$) and BRI steers were heavier than WAG steers ($P = .0004$). There tended ($P = .07$) to be a treatment \times breed interaction for slaughter weight. This was due to the CON steers on the NW treatment not being as heavy as the steers on the EW and NWC treatments. For this reason, a breed \times treatment interaction was also observed for 205 d - slaughter ADG ($P = .02$), DMI ($P = .01$), and total feed consumed ($P = .02$).

The EW steers had more days fed than NWC and NW steers ($P = .0001$), and the NWC steers had fewer days fed than NW steers ($P = .0002$). The BRI steers responded similarly to the BRI steers in year one. No differences ($P > .54$) were detected for days fed between the BRI and CON steers. The WAG steers were fed for a longer period of time ($P = .003$) compared to the BRI steers.

EW steers had higher gains ($P = .0001$) prior to 205 d than NWC and NW steers, and NWC steers gained more ($P = .0001$) than the NW steers. These treatment results are similar to year one. No breed differences ($P > .38$) were observed. No differences ($P > .23$) in gain were observed between EW vs NWC and NW steers between 205 d and slaughter. NWC steers tended to exhibit higher gains ($P = .07$) between 205 d and slaughter than NW steers. No differences were observed between BRI and CON steers ($P > .10$), but BRI steers gained more ($P = .0001$) between 205 d and slaughter than WAG steers. EW steers had higher gains ($P = .0006$) during the entire study compared to NWC and NW steers, and NWC steers had higher gains ($P = .003$) than NW steers.

In the feedlot, EW steers had lower intakes (7.29 vs 7.68 kg/d, $P = .0008$) and better feed conversion (.160 vs .141, $P = .0001$) compared to NWC and NW steers. NWC steers had higher intakes (7.86 vs 7.50 kg/d, $P = .003$) than NW steers, and no differences ($P > .19$) were observed in efficiency. BRI steers had lower intakes (7.54 vs 7.97 kg/d, $P = .008$) than CON steers, and WAG steers had lower intakes (7.14 vs 7.54 kg/d, $P = .001$) than BRI steers. No differences ($P > .65$) were observed between BRI and CON steers in feed conversions, but the BRI steers were more efficient ($P = .002$) than WAG steers. EW steers consumed more (1950 vs 1767 kg, $P = .0001$) than NWC and NW steers, and NWC steers tended ($P = .07$) to consume more total feed than the NW steers. BRI steers consumed less (1786 vs 1926 kg, $P = .0001$) total feed than CON steers, and no differences ($P > .63$) were observed between BRI and WAG steers.

No treatment \times breed interactions were observed ($P > .10$) for carcass traits. Tables 5 and 6 present the main effects of treatment and breed, respectively, for year two. EW steers had heavier carcasses (283 vs 274 kg, $P = .04$) than NWC and NW steers, and there were no differences ($P > .42$) observed between NWC and NW steers. Longissimus muscle area was not affected ($P > .59$) by treatment. EW steers had more (2.3 vs 2.1, $P = .0005$) kidney, pelvic, and heart fat than NWC and NW steers, and NWC steers had more (2.2 vs 1.9, $P = .001$) kidney, pelvic, and heart fat than NW steers. Differences in kidney, pelvic, and heart fat are reflected in differences in USDA yield grades. EW steers had a higher USDA yield grade (2.71 vs 2.62, $P = .03$) than NWC and NW steers, and NWC steers had a higher USDA yield grade (2.67 vs. 2.57, $P = .03$) than NW steers. Sixty-one percent of the steers graded USDA yield grade 2.9 or better.

Marbling score was improved for EW compared to NWC and NW (1168 vs 1123, $P = .004$). EW improved percent grading average choice or higher by 28%. In year two, EW improved feed efficiency and quality grades. These results are similar to year one.

The carcass weights of the BRI steers were lighter (279 vs 291, $P = .01$) than the CON steers; however, the carcass weights of the BRI steers were heavier (279 vs 262, $P = .0005$) than the

WAG steers. CON steers had more (79.4 vs 73.2, $P = .0001$) longissimus muscle area than BRI steers. No difference ($P > .41$) was observed between BRI and WAG steers. When longissimus muscle area is expressed as square centimeters per kilogram of carcass weight, CON steers had an advantage (.27 vs .26, $P = .02$) over the BRI steers. Additionally, the WAG steers had an advantage (.28 vs .26, $P = .0007$) over the BRI steers, since the WAG steers had lighter carcass weights. No differences ($P > .27$) in kidney, pelvic, and heart fat were detected. The heavier carcass weights and larger longissimus muscle areas of the CON steers resulted in differences (2.54 vs 2.73, $P = .0002$) in USDA yield grades between the CON and BRI steers. No differences ($P > .17$) in USDA yield grades were observed between BRI and WAG steers. No differences ($P > .11$) in marbling score were observed between breeds. BRI steers improved percent grading choice or higher by 18% over CON steers, and improved percent grading average choice or higher by 25%. No differences ($P = .98$) were observed in grading choice or higher between BRI and WAG steers.

Effect of Early Weaning on Cow Performance. There were no interactions observed ($P > .10$) for cow performance traits between treatment \times year. Cow performance traits for year one and two are presented in Table 7. No differences ($P > .35$) in initial weight were observed between treatments. On d 205, cows with EW steers were heavier (425 vs 388, $P = .0001$) than cows with NWC and NW steers. No differences ($P > .58$) in cow weight were observed on d 205 between cows with NWC and NW steers. Cows with EW steers had higher ADG than cows with NWC and NW (0.38 vs -0.15 kg/d, $P = .0001$) steers prior to 205 d. No differences ($P > .46$) in ADG prior to 205 were observed between cows with NWC and NW steers.

No differences ($P > .52$) in initial BCS were observed between treatments. EW improved BCS change from July to September. Cows with EW steers gained BCS (0.23 vs -0.11, $P = .0008$), while cows with NWC steers lost BCS and cows with NW steers did not change. EW did not improve ($P > .51$) pregnancy rates compared to NWC and NW. Cows with NWC steers had a greater percent pregnant (81 vs 67%, $P = .03$) than cows with NW steers.

Creep feeding and early weaning increased total costs for the beef production systems (Table 8). Creep feeding decreased yardage costs (\$3.15) and increased corn cost from \$6.32 to \$14.19 depending on the price of corn. Early weaning increased yardage costs \$15.40 and increased corn cost from \$17.70 to \$30.91 depending on corn price. The increased costs in the early weaning system will be offset by increased carcass weight (11 kg), improved quality grades (28% more steers grading average choice or higher), and increased cow weight (28 kg).

CONCLUSIONS

Early weaning increased overall gain, decreased intake, improved efficiency, and improved quality grades for steers in this study. Cow performance was improved by early weaning of beef steers. Overall costs were increased by early weaning, but revenues would also be increased due to higher carcass weights and improved quality. The increased cow weight due to early weaning would also reduce cow wintering costs. In this study, short term creep feeding had no benefits and increased costs slightly compared to non creep fed steers.

REFERENCES

SAS. 1985. SAS User's Guide: Statistics (Version 5 Ed.). SAS Inst. Inc., Cary, NC.

Steel, R.G.D., and J.H. Torrie. 1980. Principles and Procedures of Statistics: A Biometrical Approach (2nd Ed.). McGraw-Hill Publishing Co., New York.

USDA. 1975. Official United States Standards for Grades of Carcass Beef. USDA Food Safety and Quality Service, Washington, D.C.

Table 1. Composition of finishing diets fed to steers.^a

Ingredient	Diet Sequence, %			
	1	2	3	4
Cracked corn	63.80	72.84	77.82	82.81
Soybean meal	3.62	3.57	3.60	3.60
Chopped hay	30.13	19.98	14.99	10.00
Limestone	1.14	1.14	1.14	1.14
Trace mineralized salt ^b	.57	.57	.57	.57
Potassium chloride	.57	.57	.57	.57
Urea		.57	.57	.57
Thiamin	.11	.11	.11	.11
Rumensin-60 ^c	.02	.02	.02	.02
Tylan-10 ^d	.05	.05	.05	.04
Vitamin A 30,000 ^e	+	+	+	+

^aDM basis.

^bComposition (%): NaCl (82 to 87), Fe (> 2.85), Zn (> 2.30), Mn (> .22), Cu (> .20), I (> .01), Se (> .0086).

^cContains 132 g of monensin/kg.

^dContains 22 g of tylosin/kg.

^e681 IU/kg of ration.

Table 2. Main effects of weaning management system on performance traits of British crossbred steers (yr. 1).^a

Item	Treatments ^b			SEM ^c	P <	
					Contrast	
					EW vs NWC and NW	NWC vs NW
No. of pens	4	4	4			
Initial wt, kg	149	140	144	5	.27	.55
Slaughter wt ^d , kg	493	479	470	7	.17	.76
Days fed	264	213	213	2	.0001	.91
ADG, kg						
July 27 - Sept. 19	1.44	0.82	0.62	.05	.0001	.02
Sept. 19 - Slaughter	1.28	1.38	1.38	.01	.002	.87
July 27 - Slaughter	1.31	1.27	1.22	.02	.01	.10
Initial ht, cm	98.4	96.0	97.0	.99	.13	.54
Height change, cm						
July 27 - Sept. 19	8.2	7.0	5.5	.7	.04	.17
DMI, kg/d ^e	7.70	8.20	8.12	.11	.01	.62
Feed/Gain ^e	5.90	6.47	6.63	.13	.003	.41
Gain/Feed ^e	.170	.155	.151	.003	.002	.39
Total Feed, kg ^f	2033	1853	1728	30	.0001	.02

^aLeast squares means.

^bEW = early weaned, NWC = normal weaned with creep, NW = normal weaned.

^cGreatest standard error of treatment means (SEM) reported.

^dCalculated as hot carcass weight/.61.

^eDuring feedlot phase.

^fCreep and feedlot phases included.

Table 3. Main effects of weaning management system on carcass quality traits of British Crossbred Steers (yr. 1).^a

Item	Treatments ^b			SEM ^c	P <	
					Contrast	
					EW vs NWC and NW	NWC vs NW
No. of steers	27	28	28			
Carcass wt, kg	301	290	289	6	.11	.97
LMA ^d						
Sq. cm	74.5	73.6	74.0	1.26	.65	.83
Sq. cm/kg carcass wt	.25	.26	.26	.01	.18	.77
Est. KPH ^e , %	1.8	1.5	1.8	.1	.09	.03
USDA Yield grade	2.86	2.74	2.79	.04	.07	.50
Marbling score ^f	1198	1144	1120	18	.003	.34
% ≥ USDA Choice	99	96	100	2	.49	.14
% ≥ USDA Avg. Choice	92	67	67	8	.01	.99
% ≥ USDA Prime	14	10	0	5	.15	.15

^aLeast squares means.

^bEW = early weaned, NWC = normal weaned with creep, NW = normal weaned.

^cGreatest standard error of treatment means (SEM) reported.

^dLongissimus muscle area.

^eKidney, pelvic, heart fat.

^f1100 = Modest⁰⁰.

Table 4. Main effects of weaning management system on performance of steers of various breed type (yr. 2).^a

Item	Treatments ^{b,c}												SEM ^d	P <				Treatment x Breed		
	EW						NWC							Contrast						
	BRI	CON	WAG	BRI	CON	WAG	BRI	CON	WAG	BRI	CON	WAG		BRI	NWC	EW vs NWC	vs		BRI	vs
No. of pens	4	2	2	2	2	2	4	2	2	2	4	2	2	2						
Initial wt, kg	154	164	152	152	160	147	147	155	140	140	147	155	140	4	.009	.03	.01	.01	.06	.94
Slaughter wt ^f , kg	459	507	435	453	476	427	453	456	424	424	453	456	424	7	.004	.22	.01	.01	.0004	.07
Days fed	264	265	275	210	214	218	224	228	241	241	224	228	241	6	.0001	.0002	.54	.003	.83	
ADG, kg																				
July 25 - Sept. 18	1.00	1.07	1.05	0.88	0.87	0.73	0.60	0.63	0.61	0.61	0.60	0.63	0.61	.06	.0001	.0001	.51	.38	.19	
Sept. 18 - Slaughter	1.20	1.37	1.04	1.21	1.27	1.12	1.22	1.18	1.04	1.04	1.22	1.18	1.04	.05	.23	.07	.10	.0001	.02	
July 25 - Slaughter	1.15	1.30	1.04	1.14	1.19	1.03	1.10	1.07	0.96	0.96	1.10	1.07	0.96	.04	.0006	.003	.07	.0001	.04	
Initial ht, cm	92.1	94.0	92.8	92.4	93.9	91.1	91.5	94.1	90.6	90.6	91.5	94.1	90.6	1.0	.19	.54	.02	.33	.60	
Height change, cm																				
July 25 - Sept. 18	12.9	13.9	13.0	14.7	14.2	14.9	12.7	11.6	13.8	13.8	12.7	11.6	13.8	.6	.29	.0001	.67	.16	.06	
Sept. 18 - Slaughter	19.3	19.9	18.2	17.9	19.8	15.7	20.1	22.1	18.9	18.9	20.1	22.1	18.9	1.1	.92	.0009	.09	.02	.59	
July 25 - Slaughter	32.2	33.8	31.3	32.5	34.0	30.6	32.8	33.7	32.7	32.7	32.8	33.7	32.7	1.0	.57	.25	.11	.09	.59	
DMI, kg/d ^f	6.95	8.00	6.91	7.87	8.33	7.39	7.80	7.58	7.11	7.11	7.80	7.58	7.11	.18	.0008	.003	.008	.001	.01	
Feed/Gain ^f	6.03	6.13	6.62	6.90	7.02	7.16	7.10	7.06	7.42	7.42	7.10	7.06	7.42	.19	.0001	.15	.71	.002	.70	
Gain/Feed ^f	.166	.163	.151	.145	.142	.140	.141	.142	.135	.135	.141	.142	.135	.004	.0001	.19	.65	.002	.51	
Total Feed, kg ^g	1828	2122	1901	1779	1917	1701	1750	1739	1709	1709	1750	1739	1709	58	.0001	.07	.007	.63	.02	

^aLeast squares means.

^bEW = early weaned, NWC = normal weaned with creep, NW = normal weaned.

^cBRI = Angus x Hereford, CON = Simmental x Angus, WAG = Wagyu x Angus.

^dGreatest standard error of treatment means (SEM) reported.

^eCalculated as hot carcass weight/.61.

^fDuring feedlot phase.

^gCreep and feedlot phases included.

Table 5. Main effects of weaning management system on carcass quality traits of steers of various breed type (yr. 2).^a

Item	Treatments ^b			SEM ^c	<i>P</i> <	
					Contrast	
					EW vs NWC and NW	NWC vs NW
No. of steers	48	55	64			
Carcass wt, kg	283	276	272	4	.04	.42
LMA ^d						
Sq. cm	75.4	74.5	75.0	1.0	.59	.71
Sq. cm/kg carcass wt	.27	.27	.28	.01	.05	.14
Est. KPH ^e , %	2.3	2.2	1.9	.2	.0005	.001
USDA Yield grade	2.71	2.67	2.57	.04	.03	.03
Marbling score ^f	1168	1124	1122	13	.004	.89
% ≥ USDA Choice	95	87	91	4	.16	.39
% ≥ USDA Avg. Choice	81	58	58	6	.003	.99
% ≥ USDA Prime	15	10	2	4	.06	.15

^aLeast squares means.

^bEW = early weaned, NWC = normal weaned with creep, NW = normal weaned.

^cGreatest standard error of treatment means (SEM) reported.

^dLongissimus muscle area.

^eKidney, pelvic, heart fat.

^f1100 = Modest⁰⁰.

Table 6. Main effects of breed type on carcass quality traits of steers (yr. 2).^a

Item	Breeds ^b			SEM ^c	<i>P</i> <	
					Contrast	
	BRI	CON	WAG		BRI vs CON	BRI vs WAG
No. of steers	83	40	44			
Carcass wt, kg	279	291	262	4	.01	.0005
LMA ^d						
Sq. cm	73.2	79.4	72.2	1.1	.0001	.41
Sq. cm/kg carcass wt	.26	.27	.28	.01	.02	.0007
Est. KPH ^e , %	2.1	2.1	2.2	.1	.88	.27
USDA Yield grade	2.73	2.54	2.67	.04	.0002	.17
Marbling score ^f	1148	1120	1146	15	.11	.89
% ≥ USDA Choice	97	80	97	4	.0006	.98
% ≥ USDA Avg. Choice	72	54	71	6	.04	.84
% ≥ USDA Prime	8	10	9	4	.62	.79

^aLeast squares means.^bBRI = Angus x Hereford, CON = Simmental x Angus, WAG = Wagyu x Angus.^cGreatest standard error of treatment means (SEM) reported.^dLongissimus muscle area.^eKidney, pelvic, heart fat.^f1100 = Modest⁰⁰.

Table 7. Main effects of weaning management system on cow performance traits (yr. 1 and 2).^a

Item	Treatments ^b			SEM ^c	P <	
					Contrast	
					EW vs NWC and NW	NWC vs NW
July wt, kg	405	398	394	7	.35	.73
Sept wt, kg	425	391	385	8	.0001	.58
ADG, kg	0.38	-0.13	-0.17	.04	.0001	.46
July BCS ^d	3.9	4.0	4.0	.1	.52	.77
Sept BCS ^d	4.2	3.8	4.0	.1	.02	.06
BCS change ^d	0.23	-0.21	0.00	.08	.0008	.06
% Pregnancy	78	81	67	4.8	.51	.03

^aLeast squares means.

^bEW = early weaned, NWC = normal weaned with creep, NW = normal weaned.

^cGreatest standard error of treatment means (SEM) reported.

^dBody Condition Score (1=emaciated, 9=extremely fat).

Table 8. Change in cost due to creep feeding or early weaning at four corn prices.^a

Item	Yardage	Corn Price			
		\$2.00	\$2.50	\$3.00	\$3.50
Creep feeding	\$-3.15	\$+6.32	\$+7.84	\$+9.44	\$+14.19
Early weaning	\$+15.40	\$+17.70	\$+21.95	\$+26.43	\$+30.91

^aAll other costs held constant except yardage at \$0.35/d.

THE INFLUENCE OF PROCESSED CORN AND SUPPLEMENTAL FAT ON DIGESTION OF LIMIT-FED DIETS AND PERFORMANCE OF BEEF COWS

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SUMMARY

In Trial 1, 135 Angus \times Simmental crossbred cows with calves were used over 2 yr to compare limit-fed corn-hay diets with ad libitum hay, and to compared cracked corn with whole corn in the limit-fed diets. Cow and calf performance was not affected ($P > .05$) by level of intake or by corn processing. In Trial 2, 48 Angus \times Hereford reciprocal crossbred primiparous cows with calves were used to determine the effect of adding 4% fat as yellow grease to a limit-fed corn-hay diet. Cow weight, cow body condition score change, and calf weight gain were not affected ($P > .05$) by supplemental fat. Milk yield and composition were not different ($P > .05$) at 52 d postpartum. At 92 d postpartum, milk production was 65% greater ($P = .01$) for the cows that received supplemental fat. In Trial 3, four ruminally cannulated Holstein steers were used to evaluate the influence of corn processing and fat supplementation on digestion. Feeding cracked corn resulted in improvements ($P < .05$) in DM and OM digestion, but resulted in decreased ($P < .05$) concentrations of acetate, acetate to propionate ratio, and total concentration of volatile fatty acids in ruminal fluid compared to whole corn. Adding 4% supplemental fat to limit-fed diets did not influence ($P > .05$) digestion. Limit-feeding a corn-hay diet is an alternative to feeding ad libitum hay that can accomplish similar cow and calf performance. Supplementation of 4% fat can be used as a supplemental energy source in a limited intake corn-hay diet without detrimental affects on digestion, lactation, or cow and calf performance.

INTRODUCTION

The cost of producing, harvesting, and storing forage for beef cows is rising steadily. High concentrate feeds are frequently less expensive than harvested forages when priced on an equivalent energy basis. Corn-based diets, fed at a restricted intake, can be used to meet the nutrient requirements and lower feed costs of beef cows in gestation and early lactation (Loerch, 1996).

There are limited data comparing whole corn to processed corn in lactating beef cow diets. Improvements in DM digestion have been observed when processed corn was fed at restricted intakes (Galyean et al., 1979a; Murphy et al., 1994), and when fed in combination with forages (Cole et al., 1976b; Galyean et al., 1976) to feedlot steers.

Although adding fat increases the energy density of the diet, it can have detrimental effects on fiber digestion (Zinn, 1989). Adding fat to dairy diets fed ad libitum has been shown to improve milk yield (DePeters et al., 1987; Cant et al., 1993). There are limited data regarding the addition of fat to lactating beef cow diets that are fed at restricted intakes. The objectives of this research were to determine the influences of corn processing and supplemental fat in limit-fed diets on digestion and cow and calf performance.

MATERIALS AND METHODS

Trial 1. One hundred thirty-five ($n = 63$, year 1; $n = 72$, year 2) Angus \times Simmental crossbred cows (596 ± 28 kg) with Simmental sired calves (38.5 ± 2.2 kg) at the Orr Research Center, Baylis, IL were used in three replications to evaluate three treatments over two years. This resulted in nine pens with seven cow-calf pairs per pen in year 1 and eight cow-calf pairs per pen in Year 2. The three treatments were: ad libitum hay, limited whole corn with hay, and limited cracked corn with hay. The diets were formulated to supply similar amounts of CP and TDN based on a predicted intake of 15.9 kg for cows receiving the ad libitum hay diet. Cows and calves had ad libitum access to a trace mineralized mineral mix (Table 1). All nutrients were supplied to meet or exceed National Research Council (NRC, 1984) recommendations. Hay fed and refused was weighed and sampled for DM determination to calculate DM intake. Cow-calf pairs were blocked by calving date and randomly assigned to treatment. The cow-calf pairs were fed treatment diets starting 24 h after parturition until the beginning of breeding (62 ± 13 d). Initial cow weights and cow body condition scores (BCS) (1 to 9 scale) were taken within 24 h of calving, prior to feeding. Cow BCS was determined by the same two experienced evaluators at each time. Calf birth weight was used as initial calf weight. Final calf weight, cow weight, and BCS were taken after cows had been fed a common diet for three days and removed from feed and water for 16 h to reduce fill differences. Calf weight, cow weight, and BCS were taken at weaning (193 ± 17 d) to determine subsequent performance. Calving rate was calculated as the number of cows that calved from the number of cows exposed. Over the two years, four cow-calf pairs were removed from the study for reasons unrelated to treatment.

Trial 2. Forty-eight Angus \times Hereford reciprocal crossbred primiparous cows (367 ± 38 kg) with calves (33.5 ± 4.9 kg) at the Dixon Springs Agricultural Center, Simpson, IL were used in four replications to evaluate two treatments. This resulted in eight pens with six cow-calf pairs per pen. The treatments were limit-fed cracked corn and hay (CON), and limit-fed cracked corn and hay with 4% supplemental fat (FAT) as yellow grease (Table 2). Cows and calves had ad libitum access to a trace mineralized mineral mix. The diets were balanced to provide similar amounts of CP and TDN and to meet or exceed all nutrient requirements (NRC, 1984). Fatty acid profile of the supplemental fat is shown in Table 3. The fat used in the diets contained 70% unsaturated fatty acids.

Feed samples were taken on d 0, 30, and 60 of the treatment period. The samples were composited, and analyzed for percentages of DM, OM, Kjeldahl N (AOAC, 1984), NDF, and ADF (Goering and Van Soest, 1970).

Cows and calves were blocked by calving date and randomly assigned to treatments 24 h after parturition and received the diet until they were placed on a common endophyte-infected tall fescue (*Festuca arundinacea* Schreb.) pasture 79 ± 14 d postpartum. Initial cow weights and BCS (1 to 9 scale) were taken within 24 h of calving, prior to feeding. Cow BCS was determined by the same two experienced evaluators at each time. Calf birth weight was used as initial calf weight. Final calf weight, cow weight, and BCS were taken after cows had been removed from feed and water for 16 h to reduce fill differences. Calf weight, cow weight, and BCS were taken

at weaning (234 ± 12 d). Calving rate was determined as the number of cows that calved from the number of cows exposed.

Milk production estimates and milk samples were obtained from the first 2 replications (12 head/trt), on d 52 and 91 postpartum by machine milking with the procedure described by Buskirk et al. (1995). Twelve hour milk weights were multiplied by two to yield an estimate of 24 h milk production.

Trial 3. Four ruminally cannulated Holstein steers (538 ± 30 kg) were used in a 2×2 factorial arrangement of treatments in a 4×4 Latin square design with 14 d periods. The four treatments were: limit-fed whole corn and hay (WC), limit-fed whole corn and hay with 4% fat (WC + FAT) as yellow grease, limit-fed cracked corn and hay (CC), and limit-fed cracked corn and hay with 4% fat (CC + FAT) as yellow grease (Table 4). Steers had ad libitum access to a trace mineralized mineral mix. The diets were balanced to be isocaloric, isonitrogenous, and to meet or exceed all nutrient requirements for lactating primiparous beef cows (NRC, 1984). Diets were fed once daily at 0800.

Total tract digestibility, fluid dilution rate, particulate passage rate, ruminal VFA, and ruminal ammonia (NH_3N) were determined following the procedures described by Tarr et al. (1994) with the exception of marker dosage. The amount of markers dosed were 7.5 g of Cr as Cr_2O_3 , 10 g of CoEDTA, and 1.24 g of $\text{YbCl}_3 \cdot 6\text{H}_2\text{O}$. Rumen fluid and particulate samples were collected at 0, 1, 3, 6, 9, 12, 15, 18, 24, 30, 36, and 72 h after feeding. Fecal grab samples were collected d 11 through 14 every 6 h each day, the sampling times being advanced 1.5 h each day to yield 16 samples that represent a 24 h period.

Feed samples were taken before and during each collection period and composited. Feed and fecal samples were dried at 55°C and ground through a Wiley mill equipped with a 2 mm screen. Samples were then analyzed for percentage of DM, OM, NDF, and ADF (Goering and Van Soest, 1970). Feed samples were also analyzed for Kjeldahl N (AOAC, 1984). Gross energy (GE) was determined for both feed and fecal samples by bomb calorimetry (AOAC, 1984). Digestible energy (DE) was determined from the gross energy of the feed and feces.

Statistical Analysis. Data for Trial 1 were analyzed using the GLM procedure of SAS (1990) for a randomized block design, with cow-calf pairs being blocked by calving date. Pen was used as the experimental unit. Dietary treatment, block, year, and their 2- and 3-way interactions were the independent variable and cow and calf performance were the dependent variables. Orthogonal contrasts were used to compare hay versus limited corn-hay treatments and whole versus cracked corn.

In Trial 2, data were analyzed using the GLM procedures of SAS (1990) with pen as the experimental unit. The addition of supplemental fat, calving-date block, and their 2-way interactions were the independent variables, and the dependent variables were cow and calf performance, milk production, and milk composition.

Data for Trial 3 were analyzed according to the GLM procedures of SAS (1990) for a 2×2 factorial arrangement of treatments in a 4×4 Latin Square design with animal, period, corn processing, fat supplementation, and corn processing \times fat supplementation interactions as the independent variables. Total tract digestibility, ruminal fermentation characteristics, and passage rate data were the dependent variables. Regression analyses of the natural log of ruminal markers concentrations over time were performed using the REG[®] procedure of SAS (1990). Fluid dilution rate and particulate passage rate were determined as the slope of the regression.

RESULTS AND DISCUSSION

Trial 1. There were no 2- or 3-way interactions ($P > .05$), therefore least square means of treatment effects are presented. Cows receiving the hay diet ad libitum consumed an average of 16.1 kg/d (Table 5) which was similar to the predicted intake of 15.9 kg/d. During the treatment period, cows receiving limited intake diets lost similar ($P > .05$) amounts of weight as cows receiving the ad libitum hay diet. Loerch (1996) observed similar performance when cows received either ad libitum hay or were limit-fed corn during gestation and postpartum. Susin et al. (1995) reported that when ME intake per day was similar, mature ewes maintained body weight when they were fed restricted levels of a high-concentrate diet, but lost weight while fed high-forage diets. Reflective of cow weight changes, cow BCS decreased during the feeding period. Change in BCS was not affected ($P > .05$) by the level of intake. Loerch (1996) observed that cows receiving ad libitum hay lost more body condition than those receiving limit-fed corn in one year of a three year study. Feeding processed corn in the limit-fed diet did not have an effect ($P > .05$) on cow weight or BCS change when compared to feeding whole corn.

Cow weights at weaning were not different ($P > .05$) and there was no difference ($P > .05$) in the amount of weight the cows lost from the end of the treatment period until weaning between limit-fed and ad libitum diets. Loerch (1996) observed that cow weights and BCS at weaning were not different when they consumed limited levels of corn or ad libitum hay. Cows that had previously consumed ad libitum hay lost similar amounts ($P > .05$) of body condition while grazing pasture compared to those that received limit-fed corn-hay diets. Cows lost similar ($P > .05$) amounts of weight when they had previously received the whole corn-hay diet compared to the cracked corn hay diet. Likewise, change in BCS from the end of the treatment until weaning was not different ($P > .05$) among treatments. Calving rate also was not influenced ($P > .05$) by intake level or by processing of corn in the limit-fed diet (98, 100, and 98%, for HAY, WC, and CC, respectively). Loerch (1996) stated that cow conception rate tended to favor limit-feeding corn compared to feeding ad libitum hay.

Calf average daily gain was not affected ($P > .05$) when their dams had ad libitum access to hay compared to receiving limited intakes of corn-hay diets (Table 5). In addition, the calves of dams that received cracked corn gained similar weight ($P > .05$) compared to calves of dams that received the whole corn. In contrast, Loerch (1996) reported that calf weaning weights tended to be improved when the cows received limit-fed corn during the winter months compared to ad libitum hay.

Trial 2. There was no calving-date block \times treatment interaction ($P > .05$), therefore least square means of treatments are presented. Dry matter intakes for the two treatment groups are shown in Table 6.

Cows fed the control diet lost the same ($P > .05$) amount of weight (Table 6) as those cows fed the diet that contained fat. The decrease in body condition of the cows was similar ($P > .05$) between treatment groups. Both groups of cows had similar ($P > .05$) amounts of weight loss and BCS change from the end of the feeding period until weaning. There was a numerical reduction in calving rate for the cows receiving FAT compared to CON (75 and 91%, respectively), but the difference was not significant.

Although the cows receiving FAT sustained a higher level of lactation during the feeding period, this increase in milk production did not influence ($P > .05$) calf gains. One possible reason for lack of difference in calf performance when milk production increased could be that the amount of protein for calf growth and development was not limiting for either treatment. In addition, the quantity of milk fat available to the calves did not increase; therefore the calves would have consumed similar amounts of energy. Calf performance from the end of the treatment period until weaning was not different ($P > .05$) between treatments.

Milk yield and composition are presented in Table 7. At 52 d postpartum, milk production was not affected ($P > .05$) by adding fat to the diet. At the second estimate, 91 d postpartum, milk production was 64.5% higher ($P = .01$) for the FAT compared to the CON treatment. When fat that contained a higher degree of unsaturation were fed to dairy cows, Nianogo et al. (1991) and Pantoja et al. (1994) observed no difference in milk yield. DePeters et al. (1987) stated that fat supplementation generally improves milk yield. Cant et al. (1993) reported feeding 4% yellow grease improved milk production of first lactation cows through an increase in fatty acid uptake by mammary tissue from blood. Milk production decreased 46.7% and 12.0% from the first to the second estimate for CON and FAT treatments, respectively. The results from this trial suggest that addition of fat to a limit-fed diet allowed the cows to achieve a greater persistency of milk production from peak lactation until the end of the feeding period. The quantity of milk produced by all cows was higher than previous reports for Angus and Angus \times Hereford cows in early lactation, but the production for the cows receiving CON at 91 d postpartum was similar to previous estimates (Hixon et al., 1982; Sacco et al., 1987; Buskirk et al., 1995).

Adding fat to the diet did not affect ($P > .05$) the percentage or amount of milk fat at the first estimate. At 91 d postpartum, 4% dietary fat resulted in a 31.9% reduction ($P < .05$) in the percentage of milk fat. Previous research has shown that adding blends of animal-vegetable fats in diets fed ad libitum to dairy cows had either decreased (DePeters et al., 1987) or did not change (Pantoja et al., 1994) milk fat percentage. Schauff et al. (1992) stated that adding 5% or more of unsaturated fatty acids to the diet would likely depress milk fat percentage. Although the percentage of milk fat was decreased due to supplemental fat, the quantity of milk fat produced per day was not different ($P > .05$) between treatments.

The percentage of solids-not-fat (SNF) was reduced ($P < .05$) for cows receiving FAT compared to CON at the first estimate even though the diets contained similar amounts of energy and

protein. The daily production of SNF was not different ($P > .05$) between the two groups. At 91 d postpartum, the percentage of SNF was lower ($P < .05$) for the cows fed the FAT treatment, but due to their higher level of milk production, the quantity of SNF was higher ($P < .05$). Several studies have shown the quantity or percentage of SNF to be unaffected by adding fat in diets fed ad libitum to dairy cows (Schauff et al., 1992; Wu et al., 1993).

The percentage of milk protein was not affected ($P > .05$) with the addition of fat to the diet. Adding dietary fat to dairy cow rations either caused a decreased (Wu et al., 1993; Pantoja et al., 1994; Elliott et al., 1995) or did not change (Nianogo et al., 1991; Schauff et al., 1992) milk protein percentage. When milk yield was similar between the two groups of beef cows, there was no difference ($P > .05$) in milk protein quantity, but when the level of milk production decreased for the CON group by 91 d postpartum, the milk protein yield was 56.2% higher ($P < .05$) for the cows that received supplemental fat.

Trial 3. There were no fat \times processing interactions ($P < .05$) for apparent total tract digestibility data, therefore least squared means of treatments are presented. When comparing whole corn to cracked corn in limit-fed diets, feeding processed corn resulted in a 11.7% improvement ($P < .05$) in DM and OM digestibilities (Table 8). When diets were fed at levels greater than two times the net energy for maintenance requirement, Turgeon et al. (1983) observed that cracking or finely grinding corn did not influence total tract digestion compared to feeding whole corn. When diets were fed less than twice maintenance, reducing corn particle size increased digestibility of DM (Galyean et al., 1979a; Murphy et al., 1994). Murphy et al. (1994) reported that the increase in digestibility was primarily the result of increased total tract starch digestibility, and that the reduced intake enhanced the improvement in starch digestion. Reducing intake of diets that contain whole corn would decrease the number of kernels, and therefore may reduce the physical action of the kernels with one another which normally aids in digestibility of the starch granule (Galyean et al., 1979b, 1981).

Neutral detergent fiber and acid detergent fiber digestibilities were not different ($P > .05$) whether the corn in the limit-fed diet was cracked or whole. Fecal output was decreased ($P < .05$) by 16.4% for the cracked corn compared to whole corn. This reduction in fecal output corresponds with the improvement in DM and OM digestibilities.

Adding fat to limit-fed diets did not affect ($P > .05$) digestibilities of DM, OM, NDF, ADF, or fecal output. Previous research has shown that adding fat to ad libitum diets either did not affect (Zinn, 1992; Ludden et al., 1995) or decreased (Boggs et al., 1987; Schauff et al., 1992) DM and OM digestibilities. The addition of fat resulted in a tendency ($P = .11$) for a reduction in NDF digestibility. Nianogo et al. (1991) reported a decrease in total tract cellulose and hemicellulose digestion when fat was fed to dairy cows. Adding fat to diets often causes a reduction in fiber digestion in the rumen (Zinn, 1989) and fats that contain a higher degree of unsaturation have a greater effect on fiber digestion (Zinn, 1989; Eastridge and Firkins, 1991). When fat was added to dairy cow rations, Pantoja et al. (1994) found a decrease in digestibility of NDF in the rumen, but no difference in total tract NDF digestibility. They concluded that adding an animal-vegetable blend of fat resulted in a shift of NDF fermentation to the lower gut.

Energy values for the feed and fecal samples are presented in Table 8. The GE of the feed and the GE intake were identical regardless of corn processing. There was a tendency ($P = .08$) for a decrease in GE output and an increase in DE for the cracked compared to whole corn diets. This increase in DE is reflective of the improved DM and OM digestibility of the cracked corn diets. Gross energy digestion was less with whole corn, compared to steamed-whole or steam-flaked corn in ad libitum diets fed to steers (Ramirez et al., 1985).

There were no differences ($P > .05$) in GE output or DE concentration of the diet regardless of fat supplementation. When ad libitum diets were fed to steers, Moore et al. (1986) reported that digestion of GE was not influenced by adding fat, and Ludden et al. (1995) found no difference in energy digestion as a percentage of GE intake. In contrast, Schauff et al. (1992) observed that DE as a percentage of GE intake decreased when fat was added to lactating dairy cow diets.

Because there were no time \times treatment interactions ($P > .05$), ruminal fermentation data were pooled over time. Ruminal pH was not affected ($P > .05$) when the corn was cracked or when fat was used in limit-fed diets (Table 9). When ad libitum diets were fed to steers, both Vance et al. (1972) and Galyean et al. (1979b) observed that corn processing did not affect ruminal pH. Previous research has shown that dietary fat in ad libitum diets did not influence ruminal pH (Zinn, 1989; Schauff et al., 1992; Pantoja et al., 1994).

Although ruminal pH was not different, feeding cracked corn caused a reduction ($P < .05$) in total concentration of VFA. The decrease in total VFA was primarily the result of a 13.9% reduction ($P < .05$) in concentration of acetate. The concentration of acetate as a percentage of total VFA was also lower ($P < .01$) for cracked compared to whole corn. Vance et al. (1972) found that when all concentrate diets were fed, the molar percentage of acetate was higher for crimped corn compared to whole corn; however, the opposite was true when corn silage was added to the diet. Cole et al. (1976a) found that increasing the roughage level from 0 to 14% in a whole shelled corn diet resulted in increased molar percentage of acetate, but this increase was not observed when cotton seed hulls were added at 21%. Concentrations of propionate, butyrate, valerate, isobutyrate, and isovalerate in ruminal fluid were not influenced ($P > .05$) by corn processing. The reduction in acetate concentration resulted in a 11.3% decrease ($P < .05$) in the acetate to propionate ratio when feeding cracked versus whole corn.

The addition of fat to the diets did not influence ($P > .05$) the concentrations of total VFA or individual VFA. No differences in concentrations of VFA were observed by Pantoja et al. (1994) or Schauff et al. (1992) when fat was added to diets. The acetate to propionate ratio also was not affected ($P > .05$) by supplemental fat. Previous research has shown either no change (Pantoja et al., 1994) or a decrease (Zinn, 1989; Schauff et al., 1992) in acetate to propionate ratio with the addition of fat.

There was a time \times fat \times processing interaction ($P = .05$) for ruminal ammonia (NH_3N) concentration so data are presented over time (Figure 1). The level of rumen NH_3N for the WC + FAT diet was significantly higher than the WC treatment, but was similar ($P > .05$) to the other treatments 1 h postfeeding. Ammonia levels for WC + FAT remained higher ($P < .05$) than the other three treatments from 3 h through 15 h postfeeding. The higher levels of rumen

NH₃N would be the result of decreased incorporation of ammonia by ruminal microbes into microbial protein. This could be the result of decreased DM and OM digestibility in both the whole corn and fat treatments, although there were no fat × processing interactions ($P > .10$) for DM and OM digestibility. By 18 h after feeding, rumen NH₃N for steers receiving WC + FAT was not different ($P > .05$) than CC + FAT and WC treatments, but remained higher ($P < .05$) than CC. Just before the next feeding, there was no difference ($P > .05$) in the NH₃N level among treatments.

Ruminal kinetics are presented in Table 9. The fluid dilution rate and particulate passage rate were not affected ($P > .05$) when cracked versus whole corn was used in the limit-fed diet. Leonard et al. (1989) did not find any difference in liquid or particle passage rate when ground corn was compared to whole corn in ad libitum diets. Retention time of steamed-whole and steam-flaked corn were lower than that of whole corn when intakes were not restricted (Ramirez et al., 1985).

Fluid dilution rate and particulate passage rate were not affected ($P > .05$) by supplemental fat. Miner and Petersen (1989) and Clary et al. (1993) reported that supplemental fat in ad libitum diets did not affect fluid dilution rate, flow rate, turnover rate, or rate of passage. Zinn (1989) stated that when yellow grease or animal-vegetable blends of fat were fed, reductions in cellulolytic activity not only resulted in decreased fiber digestion but also caused reduction in passage rate. Similar decreases in passage rates were found when partially hydrogenated tallow was fed to steers, and as the level of fat increased there was a greater reduction in passage rate (Patil et al., 1993).

IMPLICATIONS

The results of this study indicate that limit-feeding a corn-hay diet is a viable alternative to feeding ad libitum hay. Although feeding cracked corn in the limit-fed diets did improve dry matter and organic matter digestibilities, no improvements in cow or calf performance were observed. Therefore, processing of corn used in early lactation beef cow diets fed at restricted intake is not necessary to maintain adequate performance. Adding up to 4% fat can provide a supplemental energy source in a limit-fed corn-based diet without any detrimental effects on cow or calf performance, diet digestibility, or ruminal fermentation.

REFERENCES

- AOAC. 1984. Official Methods of Analysis (14th Ed.). Association of Official Analytical Chemists, Washington, DC.
- Boggs, D. L., W. G. Bergen, and D. R. Hawkins. 1987. Effects of tallow supplementation and protein withdrawal on ruminal fermentation, microbial synthesis, and site of digestion. J. Anim. Sci. 64:907-914.
- Buskirk, D. D., D. B. Faulkner, and F. A. Ireland. 1995. Increased postweaning gain of beef heifers enhances fertility and milk production. J. Anim. Sci. 73:937-946.

- Cant, J. P., E. J. DePeters, and R. L. Baldwin. 1993. Mammary uptake of energy metabolites in dairy cows fed fat and its relationship to milk protein depression. *J. Dairy Sci.* 76:2254-2265.
- Clary, E. M., R. T. Brandt, Jr., D. L. Harmon, and T. G. Nagaraja. 1993. Supplemental fat and ionophores in finishing diets: Feedlot performance and ruminal digesta kinetics in steers. *J. Anim. Sci.* 71:3115-3123.
- Cole, N. A., R. R. Johnson, and F. N. Owens. 1976a. Influence of roughage level on the site and extent of digestion of whole shelled corn by beef steers. *J. Anim. Sci.* 43:483-489.
- Cole, N. A., R. R. Johnson, and F. N. Owens. 1976b. Influence of roughage level and corn processing method on the site and extent of digestion by beef steers. *J. Anim. Sci.* 43:490-496.
- DePeters, E. J., S. J. Taylor, C. M. Finley, and T. R. Famula. 1987. Dietary fat and nitrogen composition of milk from lactating cows. *J. Dairy Sci.* 70:1192-1201.
- Eastridge, M. L., and J. L. Firkins. 1991. Feeding hydrogenated fatty acids and triglycerides to lactating dairy cows. *J. Dairy Sci.* 74:2610-2616.
- Elliott, J. P., J. K. Drackley, G. C. Fahey, Jr., and R. D. Shanks. 1995. Utilization of supplemental fat by dairy cows fed diets varying in content of nonstructural carbohydrates. *J. Dairy Sci.* 78:1512-1525.
- Galyean, M. L., D. G. Wagner, and R. R. Johnson. 1976. Site and extent of starch digestion in steers fed processed corn rations. *J. Anim. Sci.* 43:1088-1094.
- Galyean, M. L., D. G. Wagner, and F. N. Owens. 1979a. Level of feed intake and site and extent of digestion of high concentrate diets by steers. *J. Anim. Sci.* 49:199-203.
- Galyean, M. L., D. G. Wagner, and F. N. Owens. 1979b. Corn particle size and site and extent of digestion by steers. *J. Anim. Sci.* 49:204-210.
- Galyean, M. L., D. G. Wagner, and F. N. Owens. 1981. Dry matter and starch disappearance of corn and sorghum as influenced by particle size and processing. *J. Dairy Sci.* 64:1804-1812.
- Goering, H. K., and P. J. Van Soest. 1970. Forage fiber analyses (apparatus, reagents, procedures, and some applications). *Agric. Handbook 379*. ARS, USDA, Washington, DC.
- Hixon, D. L., G. C. Fahey, Jr., D. J. Kesler, and A. L. Neumann. 1982. Effects of creep feeding and monensin on reproductive performance and lactation of beef heifers. *J. Anim. Sci.* 55:467-474.

- Leonard, E. S., K. R. Pond, R. W. Harvey, and R. G. Crickenberger. 1989. Effects of corn grinding and time of corn feeding on growth, starch utilization and digesta passage characteristics on growing steers fed hay-based diets. *J. Anim. Sci.* 67:1603-1611.
- Loerch, S. C. 1996. Limit-feeding corn as an alternative to hay for gestating beef cows. *J. Anim. Sci.* 74:1211-1216.
- Ludden, P. A., M. J. Cecava, and K. S. Hendrix. 1995. The value of soybean hulls as a replacement for corn in beef cattle diets formulated with or without added fat. *J. Anim. Sci.* 73:2706-2711.
- Miner, J. L., and M. K. Petersen. 1989. The effects of ruminal escape protein or fat on ruminal characteristics of pregnant winter-grazing beef cows. *J. Anim. Sci.* 67:2782-2791.
- Moore, J. A., R. S. Swingle, and W. H. Hale. 1986. Effects of whole cottonseed, cottonseed oil or animal fat on digestibility of wheat straw diets by steers. *J. Anim. Sci.* 63:1267-1273.
- Murphy, T. A., F. L. Fluharty, and S. C. Loerch. 1994. The influence of intake level and corn processing on digestibility and ruminal metabolism in steers fed all-concentrate diets. *J. Anim. Sci.* 72:1608-1615.
- Nianogo, A. J., H. E. Amos, M. A. Froetschel, and C. M. Keery. 1991. Dietary fat, protein degradability, and calving season: Effects on nutrient use and performance of early lactation cows. *J. Dairy Sci.* 74:2243-2255.
- NRC. 1984. *Nutrient Requirements of Beef Cattle* (6th Ed). National Academy Press, Washington, DC.
- Pantoja, J., J. L. Firkins, M. L. Eastridge, and B. L. Hull. 1994. Effects of fat saturation and source of fiber on site of nutrient digestion and milk production by lactating dairy cows. *J. Dairy Sci.* 77:2341-2356.
- Patil, A. R., A. L. Goetsch, P. K. Lewis, Jr., and C. E. Heird. 1993. Effects of supplementing growing steers with high levels of partially hydrogenated tallow on feed intake, digestibility, live weight gain, and carcass characteristics. *J. Anim. Sci.* 71:2284-2292.
- Ramirez, R. G., H. E. Kiesling, M. L. Galyean, G. P. Lofgreen, and J. K. Elliott. 1985. Influence of steam-flaked, steamed-whole or whole shelled corn on performance and digestion in beef steers. *J. Anim. Sci.* 61:1-8.
- Sacco, R. E., J. F. Baker, and T. C. Cartwright. 1987. Production characters of primiparous females of a five-breed diallel. *J. Anim. Sci.* 64:1612-1618.
- SAS. 1990. *SAS/STAT® Users's Guide* (Version 6, 4th Ed.). SAS Inst., Cary, NC.

- Schauff, D. J., J. P. Elliot, J. H. Clark, and J. K. Drackley. 1992. Effects of feeding lactation dairy cows diets containing whole soybeans and tallow. *J. Dairy Sci.* 75:1923-1935.
- Susin, I., S. C. Loerch, and K. E. McClure. 1995. Effects of feeding a high-grain diet at a restricted intake on lactation performance and rebreeding of ewes. *J. Anim. Sci.* 73:3199-3205.
- Tarr, S. L., D. B. Faulkner, D. D. Buskirk, F. A. Ireland, D. F. Parrett, and L. L. Berger. 1994. The value of creep feeding during the last 84, 56, or 28 days prior to weaning on growth performance of nursing calves grazing endophyte-infected tall fescue. *J. Anim. Sci.* 72:1084-1094.
- Turgeon, O. A., Jr., D. R. Brink, and R. A. Britton. 1983. Corn particle size mixtures, roughage level and starch utilization in finishing steer diets. *J. Anim. Sci.* 57:739-749.
- Vance, R. D., R. L. Preston, E. W. Klosterman, and V. R. Cahill. 1972. Utilization of whole shelled and crimped corn grain with varying proportions of corn silage by growing-finishing steers. *J. Anim. Sci.* 35:598-605.
- Wu, Z., J. T. Huber, F. T. Sleiman, J. M. Simas, K. H. Chen, S. C. Chan, and C. Fontes. 1993. Effect of three supplemental fat sources on lactation and digestion in dairy cows. *J. Dairy Sci.* 76:3562-3570.
- Zinn, R. A. 1989. Influence of level and source of dietary fat on its comparative feeding value in finishing diets for steers: Metabolism. *J. Anim. Sci.* 67:1038-1049.
- Zinn, R. A. 1992. Comparative feeding value of supplemental fat in steam-flaked corn- and steam-flaked wheat-based finishing diets for feedlot steers. *J. Anim. Sci.* 70:2959-2969.

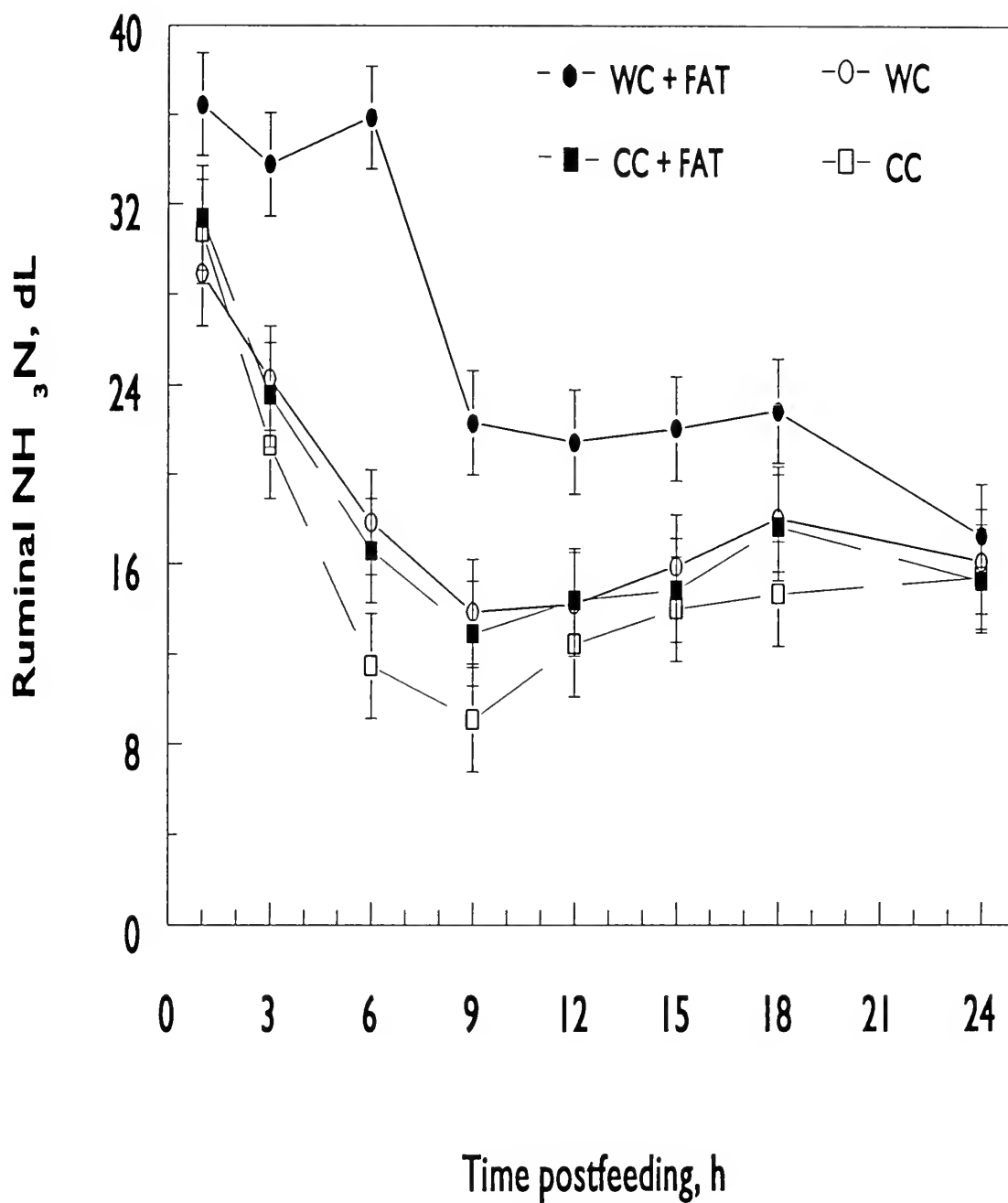


Figure 1. Effect of feeding cracked corn-hay (CC), cracked corn-hay with 4% fat (CC + FAT), whole corn-hay (WC), and whole corn-hay with 4% fat (WC + FAT) diets on ruminal NH_3N over time. WC + FAT increased ruminal NH_3N ($P < .05$).

Table 1. Composition of diets fed to postpartum cows (Trial 1).^a

	Treatments ^b		
	HAY	WC	CC
Ingredients			
Alfalfa hay, kg DM	16.0	4.5	4.5
Whole corn, kg DM	--	6.1	--
Cracked corn, kg DM	--	--	6.1
Dietary components			
	% of DM		
DM	86.9	86.3	85.9
CP	17.5	13.8	13.8
ADF	37.7	23.5	23.8
TDN	58.0	69.7	69.3

^aAnimals had ad libitum access to trace mineralized salt, composition (%): NaCl, 20-24; Ca, 14.5-16.5; P, > 8; Mg, > 1.1; S, > .71; K, > 2.24; Fe, > .25; Zn, > .25; Mn, > .25; Cu, > .03; Co, > .003; I, > .004; Se, > .0026 and vitamin A, > 529,100; vitamin D₃, > 88,183; vitamin E, > 441 IU/kg.

^bHAY = ad libitum hay, WC = limit-fed whole corn-hay, CC = limit-fed cracked corn-hay.

Table 2. Composition of diets fed to postpartum cows (Trial 2).^a

	Treatments ^b	
	CON	FAT
Ingredients		
Red clover hay, kg DM	2.27	2.27
Cracked corn, kg DM	4.58	3.90
Soybean meal (44 %), kg DM	1.00	1.13
Supplemental fat, kg DM ^{cd}	--	0.27
Dietary components		
	———— % of DM ————	————
DM	83.97	86.73
OM	93.90	95.10
CP	18.22	18.26
NDF	45.88	47.59
ADF	21.41	21.37

^aAnimals had ad libitum access to trace mineralized salt, composition (%): NaCl, 20-24; Ca, 14.5-16.5; P, >8; Mg, >1.1; S, >.71; K, >2.24; Fe, >.25; Zn, >.25; Mn, >.25; Cu, >.03; Co, >.003; I, >.004; Se, >.0026 and vitamin A, >529,100; vitamin D₃, >88,183; vitamin E, >441 IU/kg.

^bCON = limit-fed cracked corn and hay, FAT = limit-fed cracked corn and hay + 4% supplemental fat.

^cYellow grease provided by Griffin Industries, Cold Springs, KY.

^dComposition shown in Table 3.

Table 3. Fatty acid profile of supplemental fat.^a

Fatty Acid		Percent
C10:0	Capric	.09
C12:0	Lauric	.04
C14:0	Myristic	.82
C14:1	Myristoleic	.11
C15:0	Pentadecanoic	.04
C16:0	Palmitic	17.86
C16:1	Palmitoleic	1.90
C16:2	Hexadecandienoic	.08
C18:0	Stearic	9.80
C18:1	Oleic	48.01
C18:2	Linoleic	19.46
C20:0	Arachidic	1.26
C20:1	Eicosenoic	.43
C21:0	Heneicosanoic	.10
	Others	.00
	Iodine Value	77.14

^aYellow grease provided by Griffin Industries, Cold Springs, KY.

Table 4. Composition of diets fed to cannulated steers (Trial 3).^a

	Treatments ^b			
	WC	WC + FAT	CC	CC + FAT
Ingredients				
Alfalfa hay, kg DM	2.52	2.52	2.52	2.52
Cracked corn, kg DM	--	--	4.58	3.90
Whole corn, kg DM	4.58	3.90	--	--
Soybean meal, kg DM	1.00	1.18	1.00	1.18
Supplemental fat, kg DM ^{cd}	--	0.28	--	0.28
Dietary components				
	% of DM			
DM	87.24	87.28	86.97	87.62
OM	94.91	94.59	94.99	94.37
NDF	31.72	30.32	30.27	30.78
ADF	16.16	15.77	14.15	15.67
CP	18.66	19.28	17.40	19.02
DMI, kg/d	8.01	7.75	7.99	7.78

^aAnimals had ad libitum access to trace mineralized salt, composition (%): NaCl, 20-24; Ca, 14.5-16.5; P, >8; Mg, >1.1; S, >.71; K, >2.24; Fe, >.25; Zn, >.25; Mn, >.25; Cu, >.03; Co, >.003; I, >.004; Se, >.0026 and vitamin A, >529,100; vitamin D₃, >88,183; vitamin E, >441 IU/kg.

^bWC = limit-fed whole corn and hay, WC + FAT = limit-fed whole corn and hay + 4% supplemental fat, CC = limit-fed cracked corn and hay, CC + FAT = limit-fed cracked corn and hay + 4% supplemental fat.

^cYellow grease provided by Griffin Industries, Cold Spings, KY.

^dComposition shown in Table 3.

Table 5. Effects of limit feeding whole corn-hay and cracked corn-hay diets compared to ad libitum hay on cow and calf performance (Trial 1).

Item	Treatments ^a			SE	Contrast (<i>P</i> -value)	
	HAY	WC	CC		HAY vs. WC & CC	WC vs. CC
DMI, kg/d	16.1	10.6	10.6	.16	.001	1.00
Initial cow wt, kg	595	593	602	8.1	.81	.44
Cow wt change, kg/d	-.30	-.50	-.38	.08	.19	.31
Initial BCS ^b	6.19	6.17	6.22	.07	.92	.57
BCS change	-.56	-.55	-.51	.08	.74	.71
Initial calf wt, kg	38.7	37.7	39.1	.8	.75	.23
Calf wt gain, kg/d	1.18	1.09	1.15	.03	.07	.13
Subsequent performance ^c						
Cow wt change, kg/d	-.12	-.04	-.12	.03	.36	.14
BCS change	-.06	-.23	-.20	.08	.14	.83
Calf wt at weaning, kg	231	227	230	5.1	.76	.65
Calf wt gain, kg/d	.90	.93	.96	.04	.31	.53

^aHAY = ad libitum hay, WC = limit-fed whole corn-hay, CC = limit-fed cracked corn-hay.

^bBody condition score (1 to 9 scale).

^cFrom end of treatment until weaning.

Table 6. Effects of supplemental fat in a limit-fed corn-hay diet on primiparous cow and calf performance (Trial 2).

Item	Treatments ^a			P-value
	CON	FAT	SEM	
DMI, kg/d	7.44	7.38		
Initial cow wt, kg	366	368	8.0	.90
Cow wt change, kg/d	-.42	-.46	.07	.67
Initial BCS ^b	3.88	4.08	.10	.14
BCS change	.08	.04	.19	.88
Initial calf wt, kg	33.5	33.5	1.0	.96
Calf gain, kg/d	.70	.72	.02	.63
Subsequent performance ^c				
Cow wt change, kg/d	.18	.20	.04	.80
BCS change	.05	-.06	.20	.69
Calf weaning wt, kg	187	186	5.3	.92
Calf gain, kg/d	.65	.64	.02	.72

^aCON = limit-fed cracked corn and hay, FAT = limit-fed cracked corn and hay + 4% supplemental fat.

^bBody condition score of cows (1-9 scale).

^cFrom end of treatment until weaning.

Table 7. Effects of supplemental fat in a limit-fed corn-hay diet on milk production and composition (Trial 2).

Item	Treatments ^a			<i>P</i> -value
	CON	FAT	SEM	
52 d postpartum				
Milk production, kg/d	9.36	9.33	.08	.82
SNF ^b , %	8.6	8.3	.01	.02
SNF, g/d	808	772	9	.21
Fat, %	4.4	4.4	.42	.96
Fat, g/d	408	402	38	.94
Protein, %	3.0	2.9	.09	.42
Protein, g/d	260	237	8	.28
91 d postpartum				
Milk production, kg/d	4.99	8.21	.03	.01
SNF, %	9.0	8.0	.01	.01
SNF, g/d	448	661	3	.01
Fat, %	6.9	4.7	.08	.03
Fat, g/d	342	390	8	.15
Protein, %	3.1	2.9	.05	.26
Protein, g/d	153	239	1	.01

^aCON = limit-fed cracked corn and hay, FAT = limit-fed cracked corn and hay + 4% supplemental fat.

^bSolids-not-fat.

Table 8. Effects of corn processing and supplemental fat in limit-fed corn-hay diets on apparent total tract digestibility (Trial 3).

Item	Corn Processing ^a		SEM	<i>P</i>	Fat Supplementation ^b		SEM	<i>P</i>
	WC	CC			CON	FAT		
DM digestibility, %	58.9	65.8	2.0	.04	63.8	60.9	2.0	.32
OM digestibility, %	61.1	68.3	1.9	.03	66.1	63.3	1.9	.32
NDF digestibility, %	46.2	46.1	2.4	.98	49.1	43.1	2.4	.11
ADF digestibility, %	39.2	32.3	3.9	.24	37.7	33.8	3.9	.47
Fecal output, kg/d	3.23	2.70	.15	.04	2.90	3.03	.15	.54
GE feed, Mcal/kg	4.53	4.53	--	--	4.43	4.63	--	--
GE intake, Mcal/d	35.72	35.71	--	--	35.48	35.94	--	--
GE output, Mcal/d	15.22	12.92	.83	.08	13.73	14.41	.83	.56
DE, %	57.4	63.8	2.2	.08	61.3	60.0	2.2	.65
DE, Mcal/kg	2.60	2.89	.10	.08	2.72	2.77	.10	.71

^aWC = whole corn, CC = cracked corn.

^bCON = no supplemental fat, FAT = 4% supplemental fat.

Table 9. Effects of corn processing and supplemental fat in limit-fed corn-hay diets on ruminal fermentation characteristics (Trial 3).

Item	Corn Processing ^a		SEM	<i>P</i>	Fat Supplementation ^b		SEM	<i>P</i>
	WC	CC			CON	FAT		
pH	6.29	6.38	.05	.27	6.37	6.29	.05	.28
VFA, mM								
Acetate	41.97	36.14	1.18	.01	37.96	40.15	1.18	.23
Propionate	13.01	12.78	.46	.73	12.67	13.13	.46	.50
Butyrate	8.26	7.93	.20	.27	8.11	8.08	.20	.93
Valerate	.79	.75	.06	.63	.78	.77	.06	.88
Isobutyrate	.94	.94	.04	.94	.94	.94	.04	.96
Isovalerate	1.22	1.23	.06	.92	1.22	1.22	.06	.97
Total VFA	66.20	59.77	1.73	.03	61.67	64.29	1.73	.32
Acetate:Propionate	3.25	2.88	.07	.01	3.02	3.11	.07	.39
VFA, % of total VFA								
Acetate	63.4	60.5	.51	.004	61.5	62.4	.51	.24
Propionate	19.7	21.3	.38	.02	20.5	20.5	.38	.92
Butyrate	12.5	13.3	.31	.10	13.2	12.6	.31	.20
FDR ^c , %/h	4.73	4.82	.10	.55	4.81	4.75	.10	.71
PPR ^d , %/h	1.80	1.84	.11	.80	1.93	1.71	.11	.23

^aWC = whole corn, CC = cracked corn.

^bCON = no supplemental fat, FAT = 4% supplemental fat.

^cFluid dilution rate.

^dParticulate passage rate.

LIMIT-FEEDING WET CORN GLUTEN FEED AND CORN SILAGE DIETS COMPARED TO AN AD LIBITUM HAY DIET FOR BEEF COWS

K. E. Tjardes, D. B. Faulkner, L. L. Berger, T. G. Nash, and D. D. Buskirk

SUMMARY

Sixty Angus and Angus × Simmental crossbred cows with calves in year 1 (YR1), and forty-eight Angus and Angus × Simmental crossbred cows with calves in year 2 (YR2), were used to compare a limit-fed wet corn gluten feed diet (WCGF), a limit-fed corn-silage based diet (CS), and an ad libitum oat hay diet (HAY) on animal performance. Angus cows had Angus sired calves and crossbred cows had Simmental sired calves. Cows and calves were blocked by calving date and equal number of Angus and crossbred cows were randomly assigned to treatment approximately 17 days postpartum. Cow-calf pairs remained on treatment until the beginning of the breeding season (52 ± 13 d and 59 ± 4.8 d for YR1 and YR2, respectively), when they were returned to pasture. In the first year, cows receiving HAY lost more weight ($P < .05$) than the cows receiving the limit-fed treatments. Cow performance was not different ($P > .05$) between the two restricted fed diets. In YR2, cow performance was not different ($P > .05$) between treatments. In both years of the study, cow pregnancy rate was not affected ($P > .05$) by dietary treatment. Calf performance during the trial and subsequently until weaning was not significantly changed ($P > .05$) by the diets that their dams were consuming in either year of the study. Cows can be limit-fed WCGF or corn-silage diets postpartum without any detrimental affects to cow or calf performance.

INTRODUCTION

One strategy of limit-feeding is to restrict the dry matter intake (DMI) of energy dense feedstuffs, to maintain a desired intake of energy. High concentrate diets can be fed at reduced DMI to gestating and early lactation beef cows to enable similar performance as cows fed ad libitum intake of a roughage based diet (Loerch, 1996). According to the National Research Council (NRC; 1996), corn gluten feed is considered a high concentrate feedstuff that contains a relatively high amount of neutral detergent fiber. Wet corn gluten feed (WCGF) is a blend of corn hulls, evaporated steepwater, and corn germ meal. The energy value of WCGF is estimated to be 90% of the energy value of corn due to its high level of readily fermentable fiber (Firkins et al., 1985). Not only does this feedstuff contain a high level of fiber, but WCGF also has a moderate level of protein (23.8% CP).

In a study by Jaster et al. (1984), WCGF was compared to alfalfa haylage, oatlage, and sorghum-soybean silage in diets fed to dairy heifers. Feeding WCGF increased ad libitum feed intake compared to oatlage and sorghum-soybean silage, and improved average daily gains compared to the silage treatments. Hussein and Berger (1995) stated that feeding WCGF in restricted intake diets may maximize its feeding value by increasing neutral detergent fiber digestion. The objectives of this study were to evaluate limit-fed wet corn gluten feed and corn silage diets compared to an ad libitum oat hay diet.

MATERIALS AND METHODS

Sixty Angus and Angus \times Simmental crossbred cows (603 ± 25 kg) with calves (37.6 ± 1.4 kg) in year 1 (YR1), and forty-eight Angus and Angus \times Simmental crossbred cows (641 ± 27 kg) with calves (57.7 ± 9.0 kg) in year 2 (YR2), were used in two replications to evaluate the performance of cows and calves when fed three dietary treatments. Angus cows had Angus sired calves and crossbred cows had Simmental sired calves. The three treatments were limit-fed wet corn gluten feed (WCGF), limit-fed a corn-silage based diet (CS), or ad libitum access to an oat hay diet (HAY), (Tables 1 and 2). Wet corn gluten feed was added to the HAY treatment as the protein supplement, and soybean meal was used as the protein supplement in the CS diet. The WCGF diet contained half corn-silage and half WCGF for the first 3 days in order to adapt cows to an all WCGF diet. Hay fed and refused was weighed and sampled for dry matter determination. Cows and calves had ad libitum access to trace mineralized salt. The diets were formulated to supply similar amounts of energy assuming the cows would consume hay equal to 2% of their body weight (Table 3). All other nutrients were provided to meet or exceed NRC (1984) recommendations.

Cows and calves were blocked by calving date and equal number of Angus and Angus \times Simmental cows were randomly assigned to treatment pens approximately 17 days postpartum (16.4 ± 6.4 d, and 17.6 ± 10.0 d postpartum for YR1 and YR2, respectively). Initial cow and calf weights and cow body condition scores were taken prior to feeding. The cow-calf pairs remained on treatment until the beginning of breeding (52 ± 13 d and 59 ± 4.8 d for YR1 and YR2, respectively). Final cow and calf weights and cow body condition scores were taken prior to being turned out onto a common pasture for breeding. Cow BCS were determined by two experienced evaluators. All cow and calf weights were taken after cows had been fed a common CS diet for three days and removed from feed and water for 16 h to reduce fill differences. Calf performance from the end of the trial until weaning was also evaluated. Calving rate was calculated as the number of cows that calved from the number of cows exposed. One cow-calf pair in the second year was removed from the trial due to illness unrelated to treatment.

Statistical Analysis. Effects of dietary treatment were analyzed using the GLM procedure of SAS (1990) for a randomized complete block design, with cow-calf pairs being blocked by calving date. Pen was used as the experimental unit. Dietary treatment, block, year, and their 2- and 3-way interactions were the independent variables and DMI, and cow and calf performance were the dependent variables. Orthogonal contrasts were used to compare HAY versus the limit-fed treatments, and WCGF versus CS.

RESULTS

The average low temperature in March of YR2 was more moderate than the average low temperature in YR1 (0.83°C and -1.61°C , respectively). The average low temperature in April of both years was similar (4.17°C and 3.33°C for YR1 and YR2, respectively). The intake of WCGF and corn silage decreased in YR2 compared to YR1, but the intake of oat hay increased YR2 (Table 1). The differences in intake resulted in a year \times treatment interaction ($P < .05$)

for intake. There was also a year \times treatment interaction ($P < .05$) for cow gain, so means for each year are presented.

In YR1, the amount of total digestible nutrients (TDN) intake (kg/d) was similar among treatments (Table 3). By experimental design, DMI was higher ($P < .001$) for HAY compared to limited diets and intakes were lower ($P < .001$) for WCGF compared to CS (Table 4). Initial cow weights were not different ($P > .05$) between treatments. Cows on the HAY treatment lost more weight ($P < .05$) than the cows on the limit-fed diets. Cow gains did not differ ($P > .05$) between the WCGF and CS treatments. The body condition of the cows were not influenced ($P > .05$) by treatment. The calving rates of the cows were not affected ($P > .05$) by level of intake or by feeding WCGF compared to the CS diet. Calf growth rates were not affected ($P > .05$) by the diets their dams received.

In YR2, the intake of the limit-fed diets were lower ($P < .05$) than the HAY diet (Table 5). There was no difference ($P > .05$) in DMI between the two diets fed at restricted intakes. The quality of the oat hay during YR2 was of a higher quality than YR1. Even though the percentage of crude protein (CP) was similar (8.9 and 8.5%), the percentage of acid detergent fiber (ADF) was lower (31.3% vs 50.4%) and the percentage of TDN was higher (58.5% vs 46.3%) for YR2 compared to YR1 (Table 2). The cows consumed more hay dry matter in YR2 compared to YR1, and this resulted in higher intakes of TDN (kg/d). Cow weights and cow gains were not different ($P > .05$) between the HAY and the limited diets or between the two limit-fed diets (Table 5). The increased TDN intake for cows receiving the HAY diet could have allowed them to maintain similar body weights to those receiving the other treatments. Cow calving rate was not different ($P > .05$) between the HAY and the limit-fed diets. In addition, calving rate was not influenced ($P > .05$) by feeding WCGF compared to CS.

Calf performance was not significantly affected ($P > .05$) by the diets their dams received in YR2. There was a tendency ($P = .06$) for calves whose dams had received HAY to have improved gains compared to the limit-fed treatments. Calf performance to weaning, was not significantly different due to previous treatment, but there was a tendency ($P = .08$) for the calves whose dams had received the HAY treatment to have higher weaning weights.

DISCUSSION

The lower intake of WCGF and corn silage in YR2 may have been the result of the cows being under less cold stress. As the temperature falls below the thermal neutral zone, there is an expected increase in feed intake (NRC, 1996). The increased intake of oat hay in YR2 may be the result of a higher quality forage being fed. Lower quality forage can reduce the intake of dry matter. The amount of CP and ADF are used in an empirical equation to predict DMI (Mathison et al., 1986).

In both years, cow and calf performance were not affected by either feeding WCGF or corn-silage based diets when energy intake was similar. When quality of the hay was lower and the TDN was similar, the cows receiving HAY lost more weight during the feeding period than those cows receiving the limit-fed treatments. This suggests that there were improvements in digestibility of

the limit-fed diets compared to that expected. Murphy et al. (1994b) reported that restricting intake of diets fed to steers resulted in an increase in total tract neutral detergent fiber digestion of corn-silage based diets. Reducing intake results in decreased turnover rates (Galyean et al., 1979, and Murphy et al., 1994a). Slower rates of passage allows more complete digestion of ADF and NDF of the feedstuff in the rumen (Miller and Muntifering, 1985) and increased fiber fermentation in the hindgut (Lewis and Dehority, 1985).

When the cows were offered a higher quality hay, there was increased intake of oat hay. This increase in DMI resulted in a higher level of TDN intake for the HAY treatment compared to the limit-fed treatments, however the cows receiving the limit-fed treatment performed as well as the cows receiving HAY. This also suggests that reduced intake increased digestibility compared to expected digestibility. Cow body condition change and calving rate were not different due to treatment in either year.

In both years, calf performance was not significantly affected by the diets their dams were consuming. There was a tendency ($P = .08$) for increased gains of calves whose dams received HAY in YR2. Buskirk et al. (1992) found that milk production tended to increase by 54.8% when energy intake was increased above the maintenance requirement for cows with average milking ability. A possible reason for increased calf gain could be due to an increase in milk production of their dams. Although milk production of the cows was not estimated, TDN intake increased and there may have been an increase in milk production for cows receiving HAY compared to the limit-fed diets. In addition, Staples et al. (1984) observed a decline in milk production when WCGF was added to dairy cows diets.

IMPLICATIONS

Feeding limited intakes of WCGF and CS allows for similar cow gains postpartum compared to an ad libitum oat hay diet. The treatments did not appear to have any detrimental affects on calving rate. Calf performance was not affected when their dams were consuming limited amounts of corn-silage or WCGF, compared to ad libitum oat hay. Cows can be fed restricted amounts of WCGF or corn-silage based diets postpartum without adverse effects on cow or calf performance.

REFERENCES

- Buskirk, D. D., R. P. Lemenager, and L. A. Horstman. 1992. Estimation of net energy requirements (NE_m and NE_Δ) of lactating beef cows. *J. Anim. Sci.* 70:3867.
- Firkins, J. L., L. L. Berger, and G. C. Fahey, Jr. 1985. Evaluation of wet and dry distillers grains and wet and dry corn gluten feeds for ruminants. *J. Anim. Sci.* 60:847.
- Galyean, M. L., D. G. Wagner, and F. N. Owens. 1979. Level of feed intake and site and extent of digestion of high concentrate diets by steers. *J. Anim. Sci.* 49:199.

- Hussein, H. S., and L. L. Berger. 1995. Effects of feed intake and dietary level of wet corn gluten feed on feedlot performance, digestibility of nutrients, and carcass characteristics of growing-finishing beef heifers. *J. Anim. Sci.* 73:3246.
- Jaster, E. H., C. R. Staples, G. C. McCoy, and C. L. Davis. 1984. Evaluation of wet corn gluten feed, oatlage, sorghum-soybean silage, and alfalfa haylage for dairy heifers. *J. Dairy Sci.* 67:1976.
- Lewis, S. M., and B. A. Dehority. 1985. Microbiology and ration digestibility in the hindgut of the ovine. *Appl. Environ. Microbiol.* 50:356.
- Loerch, S. C. 1996. Limit-feeding corn as an alternative to hay for gestating beef cows. *J. Anim. Sci.* 74:1211.
- Mathison, G. W., L. P. Milligan, and R. D. Weisenburger. 1986. Ruminant feed evaluation unit: Nutritive value of some Alberta feeds for cattle and sheep. Pp. 55-57 in *The 65th Annual Feeders' Day Report: Agriculture and Forestry Bulletin, Special Issue*. Edmonton: University of Alberta, Canada.
- Miller, B. G., and R. B. Muntifering. 1985. Effect of forage:concentrate on kinetics of forage fiber digestion in vivo. *J. Dairy Sci.* 68:40.
- Murphy, T. A., F. L. Fluharty, and S. C. Loerch. 1994a. The influence of intake level and corn processing on digestibility and ruminal metabolism in steers fed all-concentrate diets. *J. Anim. Sci.* 72:1608.
- Murphy, T. A., S. C. Loerch, and B. A. Dehority. 1994b. The influence of restricted feeding on site and extent of digestion and flow of nitrogenous compounds to the duodenum in steers. *J. Anim. Sci.* 72:2487.
- NRC. 1984. *Nutrient Requirements of Beef Cattle* (6th Ed.). National Academy Press, Washington, D.C.
- NRC. 1996. *Nutrient Requirements of Beef Cattle* (7th Ed.). National Academy Press, Washington, D.C.
- SAS. 1990. *SAS/STAT® Users's Guide* (Version 6, 4th Ed.). SAS Inst. Inc., Cary, NC.
- Staples, C. R., C. L. Davis, G. C. McCoy, and J. H. Clark. 1984. Feeding value of wet corn gluten feed for lactating dairy cows. *J. Dairy Sci.* 67:1214.

Table 1. Intake of limit-fed wet corn gluten feed, limit-fed corn silage, and ad libitum oat hay diets fed to beef cows on a dry matter basis.^a

Item	Treatments ^b		
	HAY	CS	WCGF
	kg/d		
Year 1			
Oat hay ^c	14.4	--	--
Wet corn gluten feed	1.3	--	9.5
Corn silage	--	12.4	--
Soybean meal	--	1.4	--
Year 2			
Oat hay ^c	17.2	--	--
Wet corn gluten feed	1.2	--	7.8
Corn silage	--	9.4	--
Soybean meal	--	1.4	--

^aAnimals had ad libitum access to trace mineralized salt, composition (%): NaCl, 20-24; Ca, 14.5-16.5; P, > 8; Mg, > 1.1; S, > .71; K, > 2.24; Fe, > .25; Zn, > .25; Mn, > .25; Cu, > .03; Co, > .003; I, > .004; Se, > .0026 and Vitamin A, > 529,100; Vitamin D₃, > 88,183; Vitamin E, > 441 IU/kg.

^bHAY = oat hay diet, CS = corn-silage based diet, WCGF = wet corn gluten feed diet.

^cIntake of oat hay calculated from hay fed and refused.

Table 2. Chemical composition of limit-fed wet corn gluten feed and corn silage and ad libitum oat hay used in diets fed to beef cows on a DM basis.

	Feedstuffs ^a		
	HAY	CS	WCGF
Year 1			
DM, %	85.7	54.8	42.0
CP, % of DM	8.9	6.6	20.0
TDN, % of DM	46.3	56.7	80.0
ADF, % of DM	50.4	28.0	13.0
Year 2			
DM, %	89.5	43.9	38.4
CP, % of DM	8.5	7.6	20.0
TDN, % of DM	58.5	67.4	80.0
ADF, % of DM	31.3	28.3	13.0

^aHAY = oat hay, CS = corn-silage, WCGF = wet corn gluten feed.

Table 3. Nutrient intake of beef cows limit-fed wet corn gluten feed and corn silage diets compared to an ad libitum oat hay diet.

Item	Treatments ^a		
	HAY	CS	WCGF
	kg/d		
Year 1			
CP	1.54	1.58	1.24
TDN	7.71	8.22	7.60
ADF	7.43	3.48	1.24
Year 2			
CP	1.71	1.48	1.56
TDN	11.02	7.52	6.24
ADF	5.54	2.66	1.01

^aHAY = oat hay diet, CS = corn-silage based diet, WCGF = wet corn gluten feed diet.

Table 4. Effects of limit-feeding wet corn gluten feed and corn silage diets compared to ad libitum oat hay on cow and calf performance (Year 1).

Item	Treatments ^a			SEM	Contrasts (<i>P</i> -value)	
	HAY	CS	WCGF		HAY vs WCGF & CS	WCGF vs CS
Intake, kg/d	15.7	13.8	9.5	.11	.001	.001
Initial cow wt, kg	596	596	618	24.8	.75	.60
Final cow wt, kg	554	592	610	26.6	.29	.67
Cow gain, kg/d	-.87	-.12	-.20	.06	.01	.48
Initial BCS ^b	4.85	4.65	5.05	.20	.99	.29
BCS ^b change	.25	.70	.25	.28	.58	.38
Calving rate, %	90.0	85.0	95.0	6.88	.99	.31
Initial calf wt, kg	37.3	37.8	37.6	1.48	.84	.91
Final calf wt, kg	90.8	90.0	88.9	4.02	.81	.86
Calf gain on trial, kg/d	1.06	1.05	1.01	.06	.64	.65
Subsequent calf gain, kg/d ^c	1.10	1.20	1.09	.04	.46	.17

^aHAY = oat hay diet, CS = corn-silage based diet, WCGF = wet corn gluten feed diet.

^bBody condition score (1 to 9 scale).

^cCalf gain from end of treatment period until weaning.

Table 5. Effects of limit-feeding wet corn gluten feed and corn silage diets compared to ad libitum oat hay on cow and calf performance (Year 2).

Item	Treatments ^a				Contrasts (<i>P</i> -value)	
	HAY	CS	WCGF	SEM	HAY vs WCGF & CS	WCGF vs CS
Intake, kg/d	18.4	10.8	7.8	.57	.01	.07
Initial cow wt, kg	651	642	631	28.3	.72	.81
Final cow wt, kg	629	597	613	21.4	.47	.65
Cow gain, kg/d	-.40	-.57	-.49	.15	.56	.75
Initial BCS ^b	5.21	5.55	5.09	.20	.37	.35
BCS ^b change	.88	0.65	.78	.05	.12	.21
Calving rate, %	94.3	81.8	100.0	7.35	.73	.07
Initial calf wt, kg	61.1	55.1	56.8	2.13	.19	.64
Final calf wt, kg	123	109	113	3.14	.09	.47
Calf gain on trial, kg/d	1.07	.93	.97	.03	.06	.45
Subsequent calf gain, kg/d ^c	1.12	1.08	.98	.02	.08	.11

^aHAY = oat hay diet, CS = corn-silage based diet, WCGF = wet corn gluten feed diet.

^bBody condition score (1 to 9 scale).

^cCalf gain from end of treatment period until weaning.

OVULATION RATE AND EMBRYO QUALITY OF SUPEROVULATED BEEF HEIFERS SUPPLEMENTED WITH AN ORGANIC CHELATED MINERAL

R. B. Angus, D. D. Buskirk, T. G. Nash, and D. B. Faulkner

SUMMARY

Eighty-eight (88) yearling commercial heifers were used in two separate trials to determine the effects of supplementation with an organic chelated mineral on ovulation rate and embryo quality following superovulation. Heifers were fed a roughage based diet and supplemented daily with a corn based supplement containing 5 g of either an organic chelated mineral (O) or an inorganic mineral (I). Heifers were synchronized and blood samples taken to identify those which were pubertal. Pubertal heifers were superovulated, bred by artificial insemination and embryos were recovered nonsurgically. Response to superovulation was not different due to treatment. Heifers consuming the chelated mineral produced more ($P=.05$) recoverable ovum than the control. Embryo number and quality were not significantly different between treatments. Heifer weight gain during the trial was also unaffected by treatment.

INTRODUCTION

One of the more recent techniques for exploitation of superior beef genetics is embryo transfer. The transfer of embryos from matings of elite sires and dams can produce large numbers of genetically superior animals in a shortened period of time. Embryo transfer is a procedure which requires a sizable financial commitment. A return on this investment requires that producers maximize the number of high quality embryos secured from each donor female.

Proper mineral nutrition is critical for normal function of reproductive processes in the beef cow. Recent research suggests chelation of certain minerals can increase their availability to the animal. Increased availability of certain minerals may influence the ovulation rate of superovulated beef females and increase the percentage of these ova that develop into viable, transferable embryos. The objectives of this study were to determine the effects of organic chelated mineral supplementation on ovulation rate and embryo number and quality of superovulated beef heifers.

MATERIALS AND METHODS

Trial 1. Twenty-three Angus and fifteen Angus x Simmental heifers, 11 ± 1 mo of age, were randomly allotted by breed to two dietary treatments. The trial was conducted at the University of Illinois Beef Research Facility, Urbana, IL., from November 30, 1993 to January 28, 1994. Heifers were fed a corn silage based diet and a corn based supplement (.227 kg) which included a base mineral supplement (Table 1) and an additional organic chelated mineral (O) or an inorganic mineral (I) at the rate of 5 g mineral per day for 60 days (Table 2).

Estrus was synchronized with Syncro-Mate-B® (SMB). The SMB procedure consists of an intramuscular injection of norgestomet (3.0 mg) and estradiol valerate (5.0 mg) in a sesame oil and benzyl alcohol (10%) carrier and a hydron implant that contains 6.0 mg of norgestomet. The

implant was inserted subcutaneously into the convex surface of the ear. The implants were removed at the end of nine days. To identify heifers that were pubertal, blood samples were collected 7 d after implant removal via jugular venipuncture and immediately placed on ice to prevent progesterone metabolism (Wiseman et al., 1982). Progesterone concentrations were determined by a validated enzyme immunoassay (Kesler et al., 1990). Samples with progesterone concentrations ≥ 1.5 ng/ml were considered to be from heifers exhibiting estrous cycles. Ten heifers from each treatment were found to be exhibiting estrous cycles. The remaining twenty heifers received twice daily single i.m. injections of follicle stimulating hormone (FSH) to stimulate superovulation. FSH dosage was 5, 5, 4, 4, 3, 3, 2, and 2 mg per injection respectively. Heifers that were superovulated were administered 25 mg and 15 mg of PGF_{2 α} with each of the last two FSH injections respectively. Heifers were inseminated with frozen semen from a single collection of one sire 36 and 48 h following the last PGF_{2 α} injection.

Embryos were collected nonsurgically on d 7 following the first insemination. Embryos were recovered from flushing under a stereomicroscope. Ova were counted and embryos graded by examination of morphological appearance with the microscope. Embryos were identified as either morulae or blastocyst. Those with no visible imperfections were graded as excellent (Grade 1), those with a few extruded blastomeres as fair (Grade 2), those with severe imperfections as poor (Grade 3), and those not viable (Degenerate). Collection was performed by a certified veterinarian and grading by an accredited embryologist.

Response to FSH was analyzed using the General Linear Models procedures of SAS (SAS, 1985) with animal as the experimental unit. Further analysis was conducted on only those heifers that responded to FSH treatment. The model statement contained total ova, total embryos, grade 1 embryos, grade 2 embryos, grade 3 embryos, degenerate embryos, unfertilized ova, and weight gain as dependent variables and treatment as the independent variable.

Trial 2. Fifty yearling Angus and Angus x Hereford heifers (386 ± 47 kg) were randomly allotted to two dietary treatments. The trial was conducted at the University of Illinois Beef Research Facility, Urbana, IL., from October 9, 1994 to December 12, 1994. Heifers were fed an ensiled corn shuck based diet and a corn based supplement (.454 kg) which included a base mineral supplement (Table 1) and an additional organic chelated mineral (O) or an inorganic mineral (I) at the rate of 5 g mineral per day for 60 days.

Estrus synchronization, superovulation, breeding and embryo recovery were performed according to the same procedures as in Trial 1. Twenty-two heifers from each treatment were found to be exhibiting estrous cycles and were used for the superovulation procedure.

RESULTS

No trial by treatment interaction was detected ($P > .15$) and therefore the trials were combined for data analysis. Forty-five of sixty-four cyclic heifers (21 I and 24 O) responded to superovulation treatment and provided recoverable ovum. The results of embryo recovery are listed in Table 3. Superovulatory response was not significantly different between treatments. Heifers consuming the chelated mineral provided more ($P = .05$) recoverable ovum than the controls (6.17 vs. 4.24).

Average recovery of total embryos and Grade 1, 2 and 3 embryos were similar between treatments. The number of degenerate embryos from I supplemented heifers tended to be higher ($P=.09$) than O fed heifers. The number of unfertilized ovum from O fed heifers also tended to be higher ($P=.07$) than the control. This trend was expected as total ova number was higher for O treated heifers and embryo number was similar between treatments. Heifer weight gain during the trial period was also unaffected due to treatment.

DISCUSSION

The total number of ovum recovered was significantly greater for those heifers consuming the organic chelated mineral. This indicates that ovulation rate may be improved when heifers consume a chelated mineral prior to superovulation. Neither the number nor the quality of embryos recovered were affected by supplementation with an organic chelated mineral.

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REFERENCES

- Wiseman, B. S., D. L. Vincent, P. J. Thomford, N. S. Scheffrahn, G. S. Sargent and D. J. Kesler. 1982. Changes in porcine, ovine, bovine, and equine blood progesterone concentrations between collection and centrifugation. *Anim. Reprod. Sci.* 5:157.
- Kesler, D.J., H. Khazali and R. J. Favero. 1990. Quantification of steroids via a polymer linked second antibody enzyme immunoassay system. In: *Progress in Biomedical Polymers*. Ed., C.G. Gebelein and R. L. Dunn, Plenum Publishing Co., New York, NY, p.157-170.
- SAS. 1985. SAS User's Guide. SAS Inst., Inc., Cary, NC.

Table 1. Base mineral composition.^a

Mineral	Weight, %
Salt, %	96.000 - 98.500
Zinc, %	0.350
Iron, %	0.020
Manganese, %	0.180
Iodine, %	0.010
Cobalt, %	0.006
Selenium, %	0.003

^a13.62 g/hd/d.

Table 2. Supplemental mineral composition.^a

Mineral	Control (I) ^b	Chelated (O) ^c
Zinc, %	8	8
Manganese, %	4	4
Copper, %	2	2

^a5 g/hd/d.

^bMineral in sulfate form.

^cMineral in proteinate form.

Table 3. Response to superovulation and embryo recovery results.^a

	Treatment		P Value
	Control (I)	Chelated (O)	
Response to FSH	21/32 (66%)	24/32 (75%)	.41
Embryos	2.42	2.71	.74
Grade 1	1.62	1.38	.67
Grade 2	0.67	0.63	.88
Grade 3	0.10	0.08	.90
Degenerate	0.10	0.02	.09
Unfertilized ova	1.81	3.46	.07
Total recovered	4.24	6.17	.05

^aTreatment means for heifers responding to FSH.

PERFORMANCE AND REPRODUCTIVE EFFICIENCY OF POSTPARTUM BEEF COWS FED VARYING LEVELS OF UNDEGRADED INTAKE PROTEIN

R. B. Angus, D. B. Faulkner, D. D. Buskirk, and F. A. Ireland

SUMMARY

Three hundred forty-eight (348) spring calving Angus and Angus × Hereford crossbred cows were used to determine the effects of varying levels of ruminally undegradable protein on cow-calf performance and subsequent reproduction. Cows were randomly allotted by calving date to three dietary treatments within 24 h after calving. Cows were allowed ad libitum access to endophyte-infected tall fescue hay and provided with one of three supplements (1.36 kg/d) formulated to supply 0 (L), 125 (M), or 250 (H) g/d ruminally undegradable protein until first breeding. Supplements were designed to contain similar quantities of TDN and balanced with urea to be isonitrogenous. Calf weight, cow weight, and cow body condition score (BCS) were recorded at parturition, first breeding, and weaning. Blood samples were collected weekly, 7 d following calving until synchronization of estrus with Syncro-Mate B®. Cows consuming the M supplement lost 9.9 and 5.6 kg less body weight ($P=.001$) than L and H treated cows from calving to breeding. Cow weight change from breeding to weaning was unaffected by treatment. Cow BCS was quadratically ($P=.005$) affected by the supplement from calving to breeding. Calf gain was maximized for calves from M fed dams from calving to breeding ($P=.001$) and from calving to weaning ($P=.03$). Percentage of cows calving to first breeding and calving interval were quadratically affected ($P=.001$ and $P=.03$), respectively) by level of escape protein. Pregnancy rate and overall calving rate tended ($P=.13$ and $P=.06$) to be higher for M fed cows. Supplementing cows with 125 g/d ruminally undegradable protein while consuming tall fescue hay improved cow-calf performance and reproductive efficiency.

INTRODUCTION

Improved reproductive efficiency of the cow can increase the gross income of the cow-calf producer. The most important and most inefficient period of beef cow reproduction is the postpartum anestrous period. Dunn and Kaltenbach (1980) linked nutritional status to postpartum reproductive performance. It is well accepted that limiting energy intake and body energy stores retards reproductive function (Wiltbank et al., 1962). Reproduction of cows receiving adequate energy while limited in protein is also compromised (Forero et al., 1980; Cantrell et al., 1982; Kropp et al., 1983; Hancock et al., 1984, 1985; Rakestraw et al., 1986). Ruminally undegradable protein supplementation of low quality, warm-season forage can improve beef cow weight gain (Hibberd et al., 1988), milk production (Hibberd et al. 1988) and increase calf gain (Rusche et al., 1993). Improved performance of postpartum cows contributes to increased reproductive efficiency (Butler et al., 1991).

Little research has been conducted with supplemental escape protein for beef cows consuming tall fescue. Tall fescue is the most widely used cool-season grass in the southcentral and southeastern United States (Steen et al., 1979; Pendulum et al., 1980). Tall fescue contains an endophytic fungus which can reduce feed intake, gain, and body condition which may impair reproduction

(Hemken et al., 1984; Boling et al., 1985; Thompson et al., 1987). The objective of the study was to examine the effect of supplementing varying levels of ruminally undegradable protein on cow-calf and reproductive performance of postpartum cows in low to moderate body condition, consuming average quality fescue hay.

MATERIALS AND METHODS

Performance Study. The experiment was conducted at the University of Illinois Dixon Springs Agricultural Center located near Simpson, IL, from mid-January through mid-April 1994. Three hundred forty-eight (348) Angus and Angus × Hereford crossbred cows ranging in age from three to twelve years were used to determine the effects of varying levels of ruminally undegradable protein on cow-calf performance and subsequent reproduction of cows fed endophyte-infected tall fescue hay (*Festuca Arundinacea*). Cows were randomly allotted by calving date (February 20 ± 50 d) to three treatments within 24 h after calving. During the postpartum period, cows were supplemented once daily in fenceline bunks until first breeding. Supplements were designed to supply 0 (L), 125 (M), and 250 g (H) ruminally undegradable protein (Table 1). Supplements were formulated to contain similar quantities of TDN and balanced with urea to be isonitrogenous. Supplement levels remained constant for each treatment throughout the trial. All cows were allowed ad libitum access to tall fescue hay (Table 1) and offered free choice trace mineralized salt (Table 1) while grazing dormant endophyte-infected tall fescue pasture. Tall fescue hay averaged 76.1% DM, 10.0% CP, 63.6% NDF, 37.9% ADF, and 60.5% TDN.

The beginning and end of the treatment period are referred to as calving and breeding, respectively. Cow weight was taken and body condition score (BCS) on a 1-to-9 scale (Wagner et al., 1988) was assigned by an experienced evaluator within 24 h after parturition, prior to feeding. Calves were identified and weighed within 24 h after birth and male calves were castrated. Calf birth weight was used as initial calf weight. Cow and calf weights and cow BCS were assigned at artificial insemination (AI) following a 16 h feed and water withdrawal. Final cow weight, cow BCS, calf weight, and calf hip height was recorded at weaning (157 ± 50 d) postpartum. Calf hip height was measured to a point directly over the hook bones.

Reproductive Measurements. Blood samples were collected weekly from postpartum cows 7 d following parturition until estrus synchronization to determine the days to return to estrous. Serum samples were collected from all cows via jugular venipuncture and immediately placed in crushed ice to prevent progesterone metabolism (Wiseman et al., 1982) and serum was separated by centrifugation at 1000 g for 30 min within 6 h of collection. Samples were stored at -20° C until they could be assayed for progesterone concentration. Progesterone concentration was determined by a validated enzyme immunoassay as described by Kesler et al. (1990). Cows were considered to be exhibiting an estrous cycle at the time that the first sample containing ≥ 1.5 ng/ml progesterone was taken.

Cows were divided into groups for estrus synchronization on three consecutive days. Estrus was synchronized with Syncro-Mate-B® (SMB; Sanofi Animal Health, Overland Park, KS) at an average of 52 d postpartum. The SMB procedure consists of an intramuscular injection of norgestomet (3.0 mg) and estradiol valerate (5.0 mg) in a sesame oil and benzyl alcohol (10%)

carrier and a hydron ear implant that contains 6.0 mg of norgestomet. The implant is inserted subcutaneously into the convex surface of the middle one-third of the ear. The norgestomet implant was removed at the end of nine days. Approximately 47 hours after implant removal all cows were AI. Artificial insemination was performed by one of three inseminators experienced in timed AI. Inseminator and service sire was randomly assigned at the AI. Cows were regrouped for natural breeding 5 d following AI. Cows were managed alike after this time and maintained on endophyte-infected tall fescue pastures through the fall of the year.

Cows were palpated per rectum 147 d after AI by a trained technician to determine pregnancy. Pregnancy rate was calculated as the percentage of cows that conceived of those that were exposed to artificial or natural service. Calving date was used to calculate conception rate for cows conceiving to the AI (283 ± 11 d from AI). Artificial and natural sires were of different breeds to avoid discrepancies between first and second services. Calving rate was calculated as the percentage of cows that calved of those that were exposed to artificial or natural service. Experimental procedures were conducted according to those approved by the University Laboratory Animal Care Advisory Committee.

Statistical Analysis. Effects of dietary treatment were analyzed using the General Linear Models procedures of SAS (1990). Individual animal was considered the experimental unit. The model statement for performance measurements contained cow weight change, calf gain, cow BCS change as dependent variables, dams' breed, calf sex, dams' age, and treatment as the independent variables. The model statement for reproductive measurements contained percent exhibiting estrous cycles at synchronization, pregnancy rate, first service calving rate, overall calving rate, and calving interval as dependent variables, and treatment as the independent variable. Calving date was used as a covariate in both models. Treatment means were evaluated using linear and quadratic orthogonal contrasts.

RESULTS AND DISCUSSION

Performance Study. The effect of treatment on cow performance measures are presented in Table 2. Increasing the proportion of ruminally undegradable protein in the diet resulted in a quadratic response ($P=.001$) for cow weight change from parturition to breeding. Cows consuming the M supplement lost 9.9 and 5.6 kg less body weight than L and H treated cows, respectively. Decreased body weight loss in response to escape protein supplementation has been reported previously (Hibberd et al., 1988; Dhuyvetter et al., 1993; Rusche et al., 1993). Dietary treatment did not affect cow weight change from breeding to weaning. Weight change for cows from calving to weaning was affected quadratically ($P=.01$) by postpartum diet. Cows fed M supplement lost 7 kg less body weight than either L or H treated cows. Increased weight loss of cows receiving H supplement is most likely due to energy limitation. Supplying a high proportion of escape protein in the diet can lower rumen ammonia concentration (Scott et al., 1991). Lowering rumen ammonia concentration will decrease rumen microbial activity and impair normal ruminal fiber digestion (Oldham, 1984). Decreasing fiber digestion of cows consuming high forage diets may limit energy available to the cow.

As expected, cow BCS change followed a similar pattern of significance as cow weight change. Body condition score change was slightly positive from calving to breeding for M treated cows, while BCS change was negative for L and H supplemented cows. Scott et al. (1992) reported a decrease in BCS of cows fed 50% of total protein in an undegradable form compared to cows fed 28% bypass protein.

Calf performance measures are reported in Table 3. Calf birth weight was similar for all treatments ($P > .05$). Calf gain for the treatment period demonstrated a quadratic response ($P = .001$). Gain was maximized for calves from M fed dams. The advantage in gain by calves from M supplemented cows is likely due to increased milk production. Hibberd et al. (1988) demonstrated increased milk production from cows that received additional bypass protein. Increased escape protein in isocaloric diets improved calf gain during the first 100 d and corresponded to numerical improvements in milk production (Rusche et al., 1993). Triplett et al. (1995) also demonstrated a decreased level of milk production in heifers consuming high levels of escape protein as compared to intermediate amounts. A decrease in milk production of H supplemented cows may be due to energy limitation resulting from lower rumen ammonia concentration. Early weaning was performed in anticipation of the deleterious affects often associated with grazing endophyte-infected tall fescue during late summer. Calf gain was unaffected by treatment for the period from breeding to weaning. Overall calf gain from calving to weaning was quadratically affected ($P = .03$) by treatment. The significance of this response is likely due to treatment period differences when combined with similar gain post-treatment. No difference was detected in the hip height of calves at weaning.

Calf gains are lower than previous reports for Angus and Angus-Hereford calves (Hixon et al., 1982; Nunez-Dominguez et al., 1993). This reduced performance is likely due to lower milk production of the cows. Decreased milk production of cows grazing endophyte-infected tall fescue resulted in decreased calf weaning weight compared with calves from cows that grazed low-endophyte tall fescue (Ashley et al., 1987; Keltner et al., 1988; Peters et al., 1992).

Reproductive Measurements. Measures of reproductive performance as influenced by level of ruminally undegradable protein are shown in Table 4. Percentage of cows exhibiting estrous cycles at estrus synchronization was not different due to treatment ($P = .36$). This may be due in part to the low percentage (12.1%) of cows returning to estrous prior to estrus synchronization. The percentage of cows calving to AI of those exposed to artificial or natural service was quadratically ($P = .003$) affected as percentage of protein from an undegradable source increased in the supplement. An additional 9.6 and 12.4 percent of M treated cows calved due to conception from AI compared to L and H fed cows, respectively. Percent of cows exhibiting estrous cycles prior to synchronization and first service calving rate are low. This may be a result of the poor body condition of the cows at calving and breeding. Consumption of endophyte-infected tall fescue during the prepartum period has been shown to decrease cow performance and BCS (Peters et al., 1992). Poor conception rates may also be attributable to extremely cold and wet environmental conditions throughout the treatment period. First service calving rates are greater than percent exhibiting estrous cycles at synchronization for M supplemented cows. Syncro-Mate B[®] treatment has been shown to increase the percentage of cows showing estrous soon after treatment (Odde, 1990). The significance of first service calving rate is similar to cow

weight and body condition score changes observed in this study. Greater postpartum weight gain has been shown to increase luteal activity, estrus response, and pregnancy rates (Spitzer et al., 1995). Loss of body weight and condition has been associated with a delay in the initiation of normal postpartum reproductive cyclicity (Butler et al., 1981). Pregnancy rate tended ($P=.13$) to be superior for M supplemented cows compared to cows consuming L and H supplements. Calving rate also tended ($P=.06$) to be higher for M treated cows. Advantages in pregnancy and calving rate are likely due to a larger percentage of cows conceiving earlier in the breeding season. Increased weight gain has also been shown to increase pregnancy rate (Spitzer et al., 1995). An advantage of 3.5 and 6.8 d for calving interval was significant ($P=.03$) for M fed cows compared to cows on the L and H treatments, respectively.

IMPLICATIONS

Supplements containing 125 g/d ruminally undegradable protein for postpartum beef cows consuming endophyte-infected tall fescue improves reproductive efficiency and cow-calf performance during the postpartum period compared to 0 and 250 g/d escape protein. Intermediate levels of ruminally undegradable protein decreased cow weight and body condition loss and increased calf gain. An additional 125 g/d escape protein also increased pregnancy rate, first service calving rate, overall calving rate, and calving interval. Supplementing postpartum cows with ruminally undegradable protein may improve the efficiency of beef production through increased cow-calf performance and reproductive efficiency.

REFERENCES

- Ashley, T. L., D. G. Keltner, J. B. McLaren, H. A. Fribourg, and D. Onks. 1987. Performance of crossbred cows and calves grazing fescue pastures with varying levels of *Acremonium coenophialum* infection. J. Anim. Sci. 65(Suppl. 1):49 (Abstr.).
- Boling, J. A. 1985. Endophytic fungus and tall fescue utilization by ruminants. Prof. Anim. Sci. 1:19.
- Butler, W. R., R. W. Everett, and C. E. Coppock. 1981. The relationships between energy balance, milk production and ovulation in postpartum Holstein cows. J. Anim. Sci. 53:742.
- Cantrell, J. A., J. R. Kropp, S. L. Armbruster, K. S. Lusby, R. P. Wettemann, and R. L. Hintz. 1982. The influence of postpartum nutrition and weaning age of calves on cow body condition, estrus, conception rate and calf performance of fall-calving beef cows. Okla. Agr. Exp. Sta. MP-112:53.
- Dhuyvetter, D. V., M. K. Petersen, R. P. Ansotegui, R. A. Bellows, B. Nisley, R. Brownson, and M. W. Tess. 1993. Reproductive efficiency of range beef cows fed different quantities of ruminally undegradable protein before breeding. J. Anim. Sci. 71:2586.

- Dunn, T. G., and C. C. Kaltenbach. 1980. Nutrition and the postpartum interval of the ewe, sow and cow. *J. Anim. Sci.* 51(Suppl. 2):29.
- Forero, O., F. N. Owens, and K. S. Lusby. 1980. Evaluation of slow release urea for winter supplementation of lactating range cows. *J. Anim. Sci.* 50:532.
- Hancock, K. L., J. R. Kropp, K. S. Lusby, R. P. Wettemann, D. S. Buchanan, and C. Worthington. 1984. The influence of postpartum nutrition and weaning age of calves on cow body condition, estrus, conception rate and calf performance of fall-calving beef cows. *Okla. Agr. Exp. Sta. MP-116:173.*
- Hancock, K. L., J. R. Kropp, K. S. Lusby, R. P. Wettemann, D. S. Buchanan, and C. Worthington. 1985. The influence of postpartum nutrition and weaning age of calves on cow body condition, estrus, conception rate and calf performance of fall-calving beef cows. *Okla. Agr. Exp. Sta. MP-117:180.*
- Hemken, R. W., J. A. Jackson, Jr., And J. A. Boling. 1984. Toxic factors in tall fescue. *J. Anim. Sci.* 58:1011.
- Hibberd, C. A., R. R. Scott, B. D. Trautman, and C. Worthington. 1988. Bypass protein supplementation of fall-calving beef cows grazing dormant native range. *Okla. Agr. Exp. Sta. MP-120:82.*
- Hixon, D. L., G. C. Fahey, Jr., D. J. Kesler, and A. L. Nuemann. 1982. Effects of creep feeding and monesin on reproductive performance and lactation of beef heifers. *J. Anim. Sci.* 55:467.
- Hoveland, C. S. 1993. Economic importance of Acremonium endophytes. *Agric. Ecosyst. and Environ.* 44:3.
- Keltner, D. G., J. B. McLaren, H. A. Fribourg, A. B. Chestnut, W. T. McDonald, and D. O. Onks. 1988. Performance of crossbred cows and calves grazing tall fescue with varying levels of endophyte infestation. *J. Anim. Sci.* 66(Suppl. 1):55 (Abstr.).
- Kesler, D. J., H. Khazali, and R. J. Favero. 1990. Quantification of steroids via a polymer linked second antibody enzyme immunoassay system: Methods of linking anti-rabbit IgG to polystyrene. In: C. G. Gebelein and R. L. Dunn (Ed.) *Progress in Biomedical Polymers*. Plenum Publishing Co., New York, NY, p. 157-170.
- Kropp, J. R., K. Hancock, K. S. Lusby, R. P. Wettemann, R. L. Hintz, and C. Worthington. 1983. The influence of postpartum nutrition and weaning age of calves on cow body condition, estrus, conception rate and calf performance of fall-calving beef cows. *Okla. Agr. Exp. Sta. MP-114:236.*

- Nunez-Dominguez, R., L. D. Van Vleck, and L. D. Cundiff. 1993. Breed comparisons for growth traits adjusted for within-breed genetic trend using expected progeny differences. *J. Anim. Sci.* 71:1419.
- Odde, K. G. 1990. A review of synchronization of estrus in postpartum cattle. *J. Anim. Sci.* 68:817.
- Oldham, J. D. 1984. Protein-energy interrelationships in dairy cattle. *J. Dairy Sci.* 67:1090.
- Pendulum, L. C., J. A. Boling, L. P. Bush, and R. C. Buckner. 1980. Digestibility and metabolism of Kenhy tall fescue harvested at three stages of physiological maturity. *J. Anim. Sci.* 51:704.
- Peters, C. W., K. N. Grigsby, C. G. Aldrich, J. A. Paterson, R. J. Lipsey, M. S. Kerley, and G. B. Garner. 1992. Performance, forage utilization, and ergovaline consumption by beef cows grazing endophyte fungus-infected tall fescue, endophyte fungus-free tall fescue, or orchardgrass pastures. *J. Anim. Sci.* 70:1550.
- Rakestraw, J., K. S. Lusby, R. P. Wettemann, and J. J. Wagner. 1986. Postpartum weight and body condition loss and performance of fall-calving beef cows. *Theriogenology* 26:461.
- Rusche, W. C., R. C. Cochran, L. R. Corah, J. S. Stevenson, D. L. Harmon, R. T. Brandt, Jr., and J. E. Minton. 1993. Influence of source and amount of dietary protein on performance, blood metabolites, and reproductive function of primiparous beef cows. *J. Anim. Sci.* 71:557.
- SAS. 1990. SAS/STAT® User's Guide (Version 6, 4th Ed.). SAS Inst. Inc., Cary, NC.
- Scott, R. R., C. A. Hibberd, W. W. Chan, and K. S. Swenson. 1991. Effect of supplemental bypass protein on intake, digestion and duodenal protein flow of low quality native grass hay in beef cows. *Okla. Agr. Exp. Sta. MP-134:192.*
- Scott, R. R., C. A. Hibberd, W. W. Chan, K. S. Swenson, and C. Worthington. 1992. Supplemental ruminally undegradable protein for fall calving beef cows grazing dormant native grass pastures. *Okla. Agr. Exp. Sta. MP-136:185.*
- Spitzer, J. C., D. G. Morrison, R. P. Wettemann, And L. C. Faulkner. 1995. Reproductive responses and calf birth and weaning weights as affected by body condition at parturition and postpartum weight gain in primiparous beef cows. *J. Anim. Sci.* 73:1251.
- Steen, W. W., N. Gay, J. A. Boling, R. C. Buckner, L. P. Bush, and G. Lacefield. 1979. Evaluation of Kentucky 31, G1-306, G1-307, and Kenhy tall fescue as pasture for yearling steers. II. Growth, physiological response, and plasma constituents for yearling steers. *J. Anim. Sci.* 48:618.

- Thompson, F. N., J. A. Stuedemann, J. L. Sartin, D. P. Belesky, and O. J. Devine. 1987. Selected hormonal changes with fescue summer toxicosis. *J. Anim. Sci.* 65:727.
- Triplett, B. L., D. A. Neuendorff, and R. D. Randel. 1995. Influences of undegraded intake protein supplementation on milk production, weight gain, and reproductive performance in postpartum Brahman cows. *J. Anim. Sci.* 73:3223.
- Wagner, J. J., K. S. Lusby, J. W. Oltjen, J. Rakestraw, R. P. Wettemann, and L. E. Walters. 1988. Carcass composition in mature Hereford cows: estimation and effect on daily metabolizable energy requirement during winter. *J. Anim. Sci.* 66:603.
- Wiltbank, J. N., W. W. Rowden, J. E. Ingalls, K. E. Gregory, and R. M. Koch. 1962. Effect of energy level on reproductive phenomena of mature Hereford cows. *J. Anim. Sci.* 21:219.
- Wiseman, B. S., D. L. Vincent, P. J. Thomford, N. S. Scheffrahn, G. S. Sargent, and D. J. Kesler. 1982. Changes in porcine, ovine, bovine and equine blood progesterone concentrations between collection and centrifugation. *Anim. Reprod. Sci.* 5:157.

Table 1. Forage and supplement intake, composition, and nutrient concentration on DM basis.^a

Item	Forage ^b	Supplement		
		Low	Medium	High
Intake, kg/d		1.36	1.36	1.36
Composition				
Molasses, %		5.00	5.00	5.00
Urea, %		6.06	3.03	-
Dry corn gluten feed, %		88.94	67.72	46.51
Corn gluten meal, %		-	17.83	35.65
Blood meal, %		-	6.42	12.84
Nutrient concentration				
Dry matter, %	76.1	89.7	89.4	89.0
Crude protein, %	10.0	40.2	47.4	52.2
NDF, %	63.6	36.8	26.1	26.5
ADF, %	37.9	10.0	9.1	8.8
TDN, %	60.5	77.0	77.0	77.0

^aAnimals had ad libitum access to trace mineralized salt, composition (%): NaCl, 20-24; Ca, 14.5-16.5; P, > 8; Mg, > 1.1; S, > .71; K, > 2.24; Fe, > .25; Zn, > .25; Mn, > .25; Cu, > .03; Co, > .003; I, > .004, Se, > .0026 and Vitamin A, > 529,100; Vitamin D₃, > 88,183; Vitamin E, > 441 IU/kg.

^bEndophyte-infected tall fescue.

Table 2. Cow performance as influenced by varying ruminally undegradable protein postpartum.

Item	n	Diet			SEM	Contrast ^a	
		L	M	H		L	Q
Weight at calving, kg	348	406.5	401.4	397.5	3.9	.19	.92
Weight change, kg							
Calving to breeding	348	-22.29	-12.40	-18.04	1.88	.11	.001
Breeding to weaning	345	6.00	3.38	2.11	1.87	.14	.77
Calving to weaning	345	-16.29	-9.01	-16.11	2.31	.96	.01
BCS ^b at calving	348	4.33	4.24	4.28	.06	.60	.40
BCS change							
Calving to breeding	348	-0.14	0.04	-0.18	.06	.62	.005
Breeding to weaning	345	-0.48	-0.55	-0.42	.06	.41	.18
Calving to weaning	345	-0.62	-0.51	-0.61	.07	.90	.19

^aP value of a linear (L) and quadratic (Q) affect of treatment.

^b1 to 9 scale.

Table 3. Calf performance of cows fed varying ruminally undegradable protein postpartum.

Item	n	Diet			SEM	Contrast ^a	
		L	M	H		L	Q
Birth weight, kg	348	34.5	33.5	33.9	0.5	.37	.24
Gain, kg/d							
Calving to breeding	348	0.53	0.59	0.51	.01	.53	.001
Breeding to weaning	345	0.67	0.67	0.67	.01	.93	.97
Calving to weaning	345	0.61	0.64	0.60	.01	.75	.03
Hip height at weaning, cm	345	93.9	94.7	94.2	0.5	.93	.24

^aP value of a linear (L) and quadratic (Q) affect of treatment.

Table 4. Reproductive performance of cows as influenced by varying ruminally undegradable protein postpartum.

Item	n	Diet			SEM	Contrast ^a	
		L	M	H		L	Q
Cyclic at estrous synchronization, % ^b	348	10.9	13.0	14.7	2.9	.36	.96
Pregnancy rate, % ^c	344	66.7	75.7	69.0	4.3	.69	.13
First service calving rate, % ^d	348	9.8	19.4	7.0	3.0	.50	.003
Overall calving rate, % ^e	348	64.7	74.7	64.9	4.3	.98	.06
Calving interval, d	235	373.1	369.6	376.4	2.0	.25	.03

^aP value of a linear (L) and quadratic (Q) affect of treatment.

^bPercentage of cows with serum containing ≥ 1.5 ng/ml progesterone prior to estrous synchronization.

^cPercentage of cows that conceived of those that were exposed to artificial or natural service.

^dPercentage of cows calved from conception at AI of those exposed to artificial or natural service.

^ePercentage of cows that calved of those that were exposed to artificial or natural service.

EFFECT OF INTERVAL FROM MELENGESTROL ACETATE TO PROSTAGLANDIN F_{2α} ON TIMED AND SYNCHRONIZED PREGNANCY RATES OF BEEF HEIFERS AND COWS

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SUMMARY

The objective of this experiment was to determine the optimal interval from the last day of MGA feeding to PGF_{2α} treatment on pregnancy rates of beef heifers and cows. All females (149 heifers and 399 postpartum cows) were fed MGA (.5 mg) daily for 14 d and then administered PGF_{2α} (25 mg Lutalyse®) 13, 15, and 17 d (groups 1, 2, and 3, respectively) after the last d of MGA feeding. Females not in estrus the first 52 h after PGF_{2α} treatment were artificially inseminated 72 h after PGF_{2α} treatment. Females in estrus 0-52 h and 78 h-6 d after PGF_{2α} treatment were inseminated at estrus. Blood sera (collected immediately before and 3 d after PGF_{2α} treatment) were assayed for progesterone concentrations. Pregnancy was determined 44 to 47 d after the 72-h AI by per rectum examination. The intervals from MGA feeding to PGF_{2α} that had the highest 72-h AI pregnancy rates were 17 d for heifers (43%) and 15 d for cows (43%). Heifers with a 17-d interval had a higher ($P < .05$) 72-h AI pregnancy rate than heifers with 13-d and 15-d intervals and cows with a 15-d interval had a higher ($P < .05$) 72-h AI pregnancy rate than cows with a 17-d interval. The 4-d synchronized pregnancy rates (the 72-h AI and the succeeding 3 d inseminations) for both heifers (44%) and cows (53%) were not different ($P > .05$) among groups. Fewer ($P < .05$) cows with a 17-d interval from MGA to PGF_{2α} had corpora lutea regression (by 72 h) after PGF_{2α} treatment than cows with 13-d and 15-d intervals. The authors interpret the results to indicate that the interval from MGA to PGF_{2α} treatment may influence 72-h AI pregnancy rates, optimal intervals are 17 d for heifers and 15 d for cows, and pregnancy rates are improved by insemination for 3 d after the 72-h AI.

INTRODUCTION

One method of synchronizing estrus in cattle involves the concurrent use of a progestin and a luteolysin. Melengestrol acetate (MGA) suppresses estrus and is orally effective in cattle (Zimbelman and Smith, 1966). However, post-treatment fertility in females administered MGA beyond the normal lifespan of corpora lutea is low (DeBois and Bierschwal, 1970; Beal et al., 1988; Anderson and Day, 1994). Therefore, some researchers have administered MGA for about 14 d followed by the administration of the luteolysin prostaglandin F_{2α} (PGF_{2α}) about 17 d later so that estrus may be synchronized with normal fertility (Brown et al., 1988; Jaeger et al., 1992). Synchronized pregnancy rates (6-d) to this procedure have been reported to be about 49 to 57% and are similar to pregnancy rates in females bred at non-synchronized estrus. Although effective, females are generally bred by estrus detection and only one interval from the last d of MGA feeding to PGF_{2α} treatment has been evaluated. The objective of this experiment was to determine the optimal interval from the last day of MGA feeding to PGF_{2α} treatment on 72-h and 4-d synchronized pregnancy rates of heifers and cows.

MATERIALS AND METHODS

Cross-bred beef females (149 heifers and 399 cows suckling calves) from the Dixon Springs Agricultural Center at Simpson, IL were included in this study. Heifers were 12 to 15 months of age and cows were 7 to 96 d postpartum when the experiment was initiated. All females ($n=548$) were fed (as a group) MGA (.5 mg) in 2.27 kg of ground corn daily for 14 d. The cows also received *ad libitum* fescue hay and a complete vitamin and mineral mixture. Before any treatments were initiated, females were randomly assigned to one of three groups. Prostaglandin $F_{2\alpha}$ (25 mg; 5 ml Lutalyse® sterile solution) was administered 13, 15, and 17 d (groups 1, 2 and 3, respectively) after the last day of MGA feeding. Fertile bulls outfitted with chin ball markers were included with the females during the 52 h immediately after $PGF_{2\alpha}$ treatment. At 72 h after $PGF_{2\alpha}$ treatment, all females, not already inseminated, were artificially inseminated using commercially available semen from one bull (Fig. 1). Fertile bulls outfitted with chin ball markers were included with the females 6 h-7 d after the 72-h AI. Females were observed twice a d for chin ball marks for the 2 d after $PGF_{2\alpha}$ treatment and for the 7 d after the 72-h AI (Fig. 1). The 72-h AI (72 h after $PGF_{2\alpha}$ treatment) was designated as d 0. The two d before the 72-h AI were designated as d -2 and -1. The 7 d after the 72-h AI were designated as d 1-7. Females were examined for pregnancy 44-47 d after the 72-h AI by per rectum examination.

All females were bled via jugular venipuncture immediately before $PGF_{2\alpha}$ treatment and immediately before the 72-h AI. After collection, blood was stored in ice water until centrifugation at $2,000 \times g$ within 6 h after collection (Wiseman et al., 1983). Sera were harvested after centrifugation and stored at -4°C until assayed for progesterone concentrations. Progesterone concentrations were determined using a validated progesterone ELISA (Kesler et al., 1990).

Pregnant females that were in estrus before the 72-h AI were classified as pregnant from an insemination preceding the 72-h AI. Pregnant females that were in estrus 1 to 3 d after the 72-h AI were classified as pregnant from a succeeding insemination. Pregnant females that were not in estrus before or 1-7 d after $PGF_{2\alpha}$ treatment were classified as pregnant to the 72-h AI. Pregnant females that were in estrus 1 to 3 d after the 72-h AI along with the females pregnant to the 72-h AI were classified as pregnant from the synchronized AI. A small and declining percentage of females were in estrus on d 4-7 and females pregnant to those inseminations were classified as not pregnant from either the 72-h AI or the succeeding inseminations.

Females with progesterone concentrations ≥ 1.5 ng/ml immediately before $PGF_{2\alpha}$ treatment were considered to have corpora lutea. Corpora lutea were considered to have regressed in response to $PGF_{2\alpha}$ treatment if progesterone concentrations 3 d after $PGF_{2\alpha}$ treatment (72-h AI) were < 1.0 ng/ml. Females with corpora lutea that were considered to have not regressed to the $PGF_{2\alpha}$ treatment had progesterone concentrations of $2.15 \pm .24$ ng/ml 3 d after $PGF_{2\alpha}$ treatment. Females that had corpora lutea that were considered to have regressed to the $PGF_{2\alpha}$ treatment had progesterone concentrations of $.20 \pm .02$ ng/ml 3 d after $PGF_{2\alpha}$ treatment.

Number of females in estrus, pregnancy data, number of females with corpora lutea, number of females with corpora lutea that regressed, and number of females with progesterone concentrations

< 1.0 ng/ml were analyzed by Chi-square analyses (Cochran and Cox, 1957). Progesterone concentrations in females with corpora lutea before PGF_{2α} treatment were analyzed using analysis of variance (Hicks, 1964). For the analyses of the number of females with corpora lutea, number of females with corpora lutea that regressed, number of females with progesterone concentrations < 1.0 ng/ml, and progesterone concentrations for females with corpora lutea before PGF_{2α} treatment, 8 heifers (1 for d 13, 5 for d 15, and 2 for d 17) and 12 cows (1 for d 13, 3 for d 15, and 8 for d 17) had either one or both blood samples missing and were eliminated from these analyses.

RESULTS

None of the 149 heifers were in estrus before the 72-h AI. Although only 8 of the cows were in estrus before the 72-h AI, more ($P < .05$) cows with a 13 d interval between MGA and PGF_{2α} were in estrus before the 72-h AI than cows with 15 and 17 d intervals (Table 1). Numerically, the highest percentages of heifers and cows in estrus after the 72-h AI were in estrus 1 and 2 d after the 72-h AI (Table 1). Thereafter, the percentage of females in estrus decreased to 0-1% by 6 d after the 72-h AI (Table 1). Fewer ($P < .05$) heifers with a 17 d interval between MGA and PGF_{2α} were in estrus after the 72-h AI than heifers with a 15 d interval. In contrast, fewer cows with a 15 d interval between MGA and PGF_{2α} were in estrus after the 72-h AI than cows with a 17 d interval ($P < .05$; Table 1). Cows and heifers with a 13 d interval between MGA and PGF_{2α} had similar ($P > .05$) frequencies of estrus after the 72-h AI as cows and heifers with 15 and 17 d intervals.

The number of heifers with corpora lutea before PGF_{2α} treatment was not affected ($P > .05$) by the interval from MGA to PGF_{2α} and averaged 67%. However, more ($P < .05$) cows with a 15 d interval between MGA and PGF_{2α} had corpora lutea before PGF_{2α} treatment (66%) than cows with a 13 d interval (Table 2). Progesterone concentrations in heifers with corpora lutea before PGF_{2α} treatment were similar ($P > .05$) for all three treatment groups. However, as the interval from MGA to PGF_{2α} increased in the cows, progesterone concentrations increased ($P < .05$; Table 2).

As the interval from MGA to PGF_{2α} increased in heifers, the number of heifers that had regressed corpora lutea (within 3 d) after PGF_{2α} treatment increased (Table 2). More ($P < .05$) heifers with a 17 d interval from MGA to PGF_{2α} had regressed corpora lutea after PGF_{2α} treatment than heifers with a 13 d interval (Table 2). The frequency of cows with regressed corpora lutea after PGF_{2α} treatment was not different ($P > .05$) for cows that had 13 and 15 d intervals between MGA and PGF_{2α}, however, fewer ($P < .05$) cows with a 17 d interval from MGA to PGF_{2α} had regressed corpora lutea after PGF_{2α} treatment than the other two groups.

Overall, 87% of the heifers had < 1.0 ng/ml of progesterone at the 72-h AI and this incidence was not affected ($P > .05$) by the interval from MGA to PGF_{2α}. More ($P < .05$) cows with a 15 d interval from MGA to PGF_{2α} had progesterone concentrations < 1.0 ng/ml (98%) than cows with 13 and 17 d intervals at the 72-h AI, although there was a high percentage of cows in those two groups with progesterone concentrations < 1.0 ng/ml at the 72-h AI (Table 2).

Pregnancy rates from the 72-h AI were higher ($P < .05$) for heifers with an interval of 17 d between MGA and $\text{PGF}_{2\alpha}$ than for heifers with 13 and 15 d intervals (Table 3). More cows ($P < .05$) with a 15 d interval between MGA and $\text{PGF}_{2\alpha}$ became pregnant from the 72-h AI than cows with a 17 d interval. The pregnancy rates for females bred either preceding or succeeding the 72-h AI were similar ($P > .05$) among groups and averaged 62% for all females bred both before and after the 72-h AI. Pregnancy rates from the synchronized inseminations were not different ($P > .05$) among intervals between MGA and $\text{PGF}_{2\alpha}$ and averaged 44% for the heifers and 53% for the cows (Table 3).

DISCUSSION

Although MGA is effective in suppressing estrus (Zimbelman and Smith, 1966; Chenault et al., 1990), fertility of the estrus that occurs after 14 to 18 d of administration was reduced by 40 to 50% (Patterson et al., 1989 for review). The negative effect on fertility has been reported to be due to several factors (Hill et al., 1971; Lauderdale and Ericsson, 1970; Henricks et al., 1973) and this effect occurred when MGA was administered to females beyond the normal lifespan of corpora lutea (DeBois and Bierschwal, 1970; Beal et al., 1988). More recently, it has been demonstrated that administration of MGA beyond the normal lifespan of corpora lutea allows dominant follicles to persist because MGA does not suppress pulsatile luteinizing hormone secretion (Kojima et al., 1995; Kinder et al., 1996). Persistent dominant follicles create an estradiol abundant endocrine milieu and although oocytes were competent to be fertilized, their ability to reach the 16-cell stage was compromised (Ahmad et al., 1995). Anderson and Day (1994) demonstrated that progesterone administration during MGA feeding caused regression of persistent dominant follicles and fertility of the estrus immediately after MGA withdrawal was normal.

Researchers have synchronized estrus without compromising fertility by administering a luteolytic $\text{PGF}_{2\alpha}$ about 17 d after MGA treatment (Brown et al., 1988; Plugge et al., 1990; Jaeger et al., 1992; Patterson and Corah, 1992; Yelich et al., 1995; Patterson et al., 1995). After $\text{PGF}_{2\alpha}$ treatment, females in most studies have been bred at estrus via the am/pm rule. Six-d synchronized pregnancy rates have been reported to be 49 to 57% in heifers and 15 to 68% in postpartum cows. Although this procedure is valuable, it requires estrus detection, it requires a long (approximately 37 d) treatment period, and pregnancy rates in cows have been variable. More recently females synchronized with the MGA/ $\text{PGF}_{2\alpha}$ procedure have been inseminated at a predetermined time but pregnancy rates ranged from 29-61% among locations (King et al., 1994; Larson et al., 1996).

Results of this experiment demonstrate that females synchronized with the MGA/ $\text{PGF}_{2\alpha}$ procedure may be artificially inseminated at a predetermined time. However, the interval from the last d of MGA feeding to $\text{PGF}_{2\alpha}$ treatment may influence pregnancy rates from a 72-h AI. A 17 d interval from the last d of MGA feeding to $\text{PGF}_{2\alpha}$ treatment resulted in the highest pregnancy rate (43%) from a 72-h AI for heifers. These pregnancy rates are similar to pregnancy rates from predetermined timed artificial inseminations reported for Syncro-Mate B treated females (Kesler and Favero, 1996 for review). With a 17 d interval between MGA and $\text{PGF}_{2\alpha}$ 74% of the heifers had corpora lutea before $\text{PGF}_{2\alpha}$ treatment, 97% of the corpora lutea regressed to $\text{PGF}_{2\alpha}$ treatment

before the 72-h AI, and no heifers were detected in estrus before the 72-h AI. For heifers in the other two groups (13 and 15 d intervals between MGA and PGF_{2α}), 72-h pregnancy rates were lower ($P < .05$) but 4-d synchronized pregnancy rates were not different ($P > .05$) than the 4-d synchronized pregnancy rate for the group with a 17 d interval between MGA and PGF_{2α} because of pregnancies from inseminations during the 3 d after the 72-h AI.

Cows administered PGF_{2α} 15 d after the last d of MGA feeding had a higher 72-h AI pregnancy rate (43%) than cows administered PGF_{2α} 17 d after the last d of MGA feeding. These data suggest that the 72-h pregnancy rate in the cows with a 17 d interval from MGA to PGF_{2α} were negatively affected because of a lower luteolytic response by 3 d after PGF_{2α} treatment. As for the heifers, pregnancies from the inseminations after the 72-h AI caused the 4-d synchronized pregnancy rates for all three groups to be equivalent ($P > .05$).

We hypothesized that a longer interval from MGA to PGF_{2α} treatment would enhance pregnancy rates. This hypothesis was based on females administered PGF_{2α} during various stages of the estrous cycle (King et al., 1982; Stevenson et al., 1984; Watts and Fuquay, 1985). In those studies, pregnancy rates from post-PGF_{2α} treatment inseminations were higher when PGF_{2α} was administered in the later stages of the estrous cycle. Our study with heifers supported this hypothesis although our study only included a 4 d period during the middle of the luteal phase. Based on the progesterone data, it appears that fewer cows with a 17 d interval from MGA to PGF_{2α} had regressed corpora lutea by 72 h than cows with a 15 d interval. The 4-d synchronized pregnancy rates were not different between the two groups suggesting that regression may have only been delayed. In the 18 cows that did not have regressed corpora lutea by 72 h, 10 became pregnant to a synchronized insemination and 5 of the other 8 were detected in estrus.

Previous data showed that the number of females that displayed estrus (within 5 d) after PGF_{2α} treatment was greater for females administered PGF_{2α} during the later stages of the estrous cycle, but the interval from treatment to estrus was longer for females administered PGF_{2α} during the later stages of the estrous cycle (Watts and Fuquay, 1985). However, other data has demonstrated that the frequency of and the interval to corpus luteum regression was not affected by the stage of the estrous cycle when PGF_{2α} was administered (King et al., 1982; Stevenson et al., 1984). Since the incidence of corpora lutea regression in cows administered PGF_{2α} 17 d after MGA is not consistent with all published data, it would be prudent to recommend further studies comparing the 15 and 17 d interval from MGA to PGF_{2α}. Further, the use of MGA as described in this study is not yet approved by the FDA.

Since this study was designed to mimic actual field conditions (except blood collection), cows as early as 7 d postpartum were included in the study and no other selection criteria were used. Although pregnancy rates may have been compromised because some females were anestrous (at the initiation of the study), the results are representative of results that may be obtained in the field. This study was not designed to determine the efficacy of MGA in hastening estrus in anestrous females.

IMPLICATIONS

Both heifers and cows may be artificially inseminated 72 h after estrus synchronization with the MGA (feeding for 14 d) and PGF_{2α} procedure. The interval from MGA to PGF_{2α} treatment may influence 72-h AI pregnancy rates. Optimal intervals in this study were 17 d for heifers and 15 d for cows. Insemination for 3 d after the 72-h AI improved pregnancy rates.

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REFERENCES

- Ahmad, N., F. N. Schrick, R. L. Butcher, and E. K. Inskeep. 1995. Effect of persistent follicles on early embryonic losses in beef cows. *Biol. Reprod.* 52:1129.
- Anderson, L. H. and M. L. Day. 1994. Acute progesterone administration regresses persistent dominant follicles and improves fertility of cattle in which estrus was synchronized with melengestrol acetate. *J. Anim. Sci.* 72:2955.
- Beal, W. E., J. R. Chenault, M. L. Day, and L. R. Corah. 1988. Variation in conception rates following synchronization of estrus with melengestrol acetate and prostaglandin F_{2α}. *J. Anim. Sci.* 66:599.
- Brown, L. N., K. G. Odde, M. E. King, D. E. LeFever, and C. J. Neubauer. 1988. Comparison of MGA-PGF_{2α} to Syncro-Mate B for estrous synchronization in beef heifers. *Theriogenology* 30:1.
- Chenault, J. R., J. F. McAllister, and C. W. Kasson. 1990. Synchronization of estrus with melengestrol acetate and prostaglandin F_{2α} in beef and dairy heifers. *J. Anim. Sci.* 68:296.
- Cochran, W. G. and G. M. Cox. 1957. *Experimental Design* (2nd Ed.). John Wiley & Sons, New York.
- DeBois, C. H. W. and C. J. Bierschwal, Jr. 1970. Estrous cycle synchronization in dairy cattle given a 14-day treatment of melengestrol acetate. *Am. J. Vet. Res.* 31:1545.
- Henricks, D. M., J. R. Hill, Jr., and J. F. Dickey. 1973. Plasma ovarian hormone levels and fertility in beef heifers treated with melengestrol acetate (MGA). *J. Anim. Sci.* 37:1169.

- Hicks, C. R. 1964. Fundamental Concepts in the design of Experiments. Holt, Rinehart and Winston, New York.
- Hill, J. R., Jr., D. R. Lamond, D. M. Henricks, J. F. Dickey, and G. D. Niswender. 1971. The effect of melengestrol acetate (MGA) on ovarian function and fertilization in beef heifers. *Biol. Reprod.* 4:16.
- Jaeger, J. R., J. C. Whittier, L. R. Corah, J. C. Meiske, K. C. Olson, and D. J. Patterson. 1992. Reproductive response of yearling beef heifers to a melengestrol acetate-prostaglandin $F_{2\alpha}$ estrus synchronization system. *J. Anim. Sci.* 70:2622.
- Kesler, D. J. and R. J. Favero. 1996. Estrus synchronization in beef females with norgestomet and estradiol valerate. Part 2: factors limiting and enhancing efficacy. *Agri-Practice* 17:12.
- Kesler, D. J., H. Khazali, and R. J. Favero. 1990. Quantification of steroids via a polymer linked second antibody enzyme immunoassay system: methods of linking anti-rabbit IgG to poly(styrene). In: C.G. Gebelein and R.L. Dunn (Eds.) *Progress in Biomedical Polymers*. Plenum Publishing, New York.
- Kinder, J. E., F. N. Kojima, E. G. M. Bergfeld, M. E. Wehrman, and K. E. Fike. 1996. Progestin and estrogen regulation of pulsatile LH release and development of persistent ovarian follicles in cattle. *J. Anim. Sci.* 74:1424.
- King, M. E., G. H. Kiracofe, J. S. Stevenson, and R. R. Schalles. 1982. Effect of stage of the estrous cycle on interval to estrus after $PGF_{2\alpha}$ in beef cattle. *Theriogenology* 18:191.
- King, M. E., M. J. Daniel, L. D. Teague, D. N. Schutz, and K. G. Odde. 1994. Comparison of timed insemination with insemination at estrus following synchronization of estrus with a MGA-prostaglandin system in beef heifers. *Theriogenology* 42:79.
- Kojima, F. N., J. R. Chenault, M. E. Wehrman, E. G. Bergfeld, A. S. Cupp, L. A. Werth, V. Mariscal, T. Sanchez, R. J. Kittok, and J. E. Kinder. 1995. Melengestrol acetate at greater doses than typically used for estrous synchrony in bovine females does not mimic endogenous progesterone in regulation of secretion of luteinizing hormone and 17β -estradiol. *Biol. Reprod.* 52:455.
- Larson, R. L., L. R. Corah, and C. W. Peters. 1996. Synchronization of estrus in yearling heifers with the melengestrol acetate/prostaglandin $F_{2\alpha}$ system: efficiency of timed insemination 72 hours after prostaglandin treatment. *Theriogenology* 45:851.
- Lauderdale, J. W. and R. J. Ericsson. 1970. Physiological conditions affecting the ability of cattle uteri to influence the fertilizing capacity of sperm. *Biol. Reprod.* 2:179.

- NRC. 1984. Nutrient Requirements of Beef Cattle. National Academy Press, Washington, DC.
- Patterson, D. J., G. H. Kiracofe, J. S. Stevenson, and L. R. Corah. 1989. Control of the bovine estrous cycle with melengestrol acetate (MGA): a review. *J. Anim. Sci.* 67:1895.
- Patterson, D. J. and L. R. Corah. 1992. Evaluation of a melengestrol acetate and prostaglandin $F_{2\alpha}$ system for the synchronization of estrus in beef heifers. *Theriogenology* 38:441.
- Patterson, D. J., J. B. Hall, N. W. Bradley, K. K. Schillo, B. L. Woods, and J. M. Kearnan. 1995. Improved synchrony, conception rate, and fecundity in postpartum suckled beef cows fed melengestrol acetate prior to prostaglandin $F_{2\alpha}$. *J. Anim. Sci.* 73:954.
- Plugge, B. L., G. H. Deutscher, and M. K. Nielsen. 1990. Melengestrol acetate (MGA) and prostaglandin $F_{2\alpha}$ program compared to Syncro-Mate B (SMB) for estrous synchronization utilizing AI or natural service. *Prof. Anim. Sci.* 6:29.
- Stevenson, J. S., M. K. Schmidt, and E. P. Call. 1984. Stage of estrous cycle, time of insemination, and seasonal effects on estrus and fertility of Holstein heifers after prostaglandin $F_{2\alpha}$. *J. Dairy Sci.* 67:1798.
- Watts, T. L. and J. W. Fuquay. 1985. Response and fertility of dairy heifers following injection with prostaglandin $F_{2\alpha}$ during early, middle or late diestrus. *Theriogenology* 23:655.
- Wiseman, B. S., D. L. Vincent, P. J. Thomford, N. S. Scheffrahn, G. F. Sargent, and D. J. Kesler. 1983. Changes in porcine, ovine, bovine, and equine blood progesterone concentrations between collection and centrifugation. *Anim. Reprod. Sci.* 5:161.
- Yelich, J. V., H. S. Mauck, M. D. Holland, and K. G. Odde. 1995. Synchronization of estrus in suckled postpartum beef cows with melengestrol acetate and $PGF_{2\alpha}$. *Theriogenology* 43:389.
- Zimbelman, R. G. and L. W. Smith. 1966. Control of ovulation in cattle with melengestrol acetate. I. Effect of dosage and route of administration. *J. Reprod. Fertil.* 11:185.

Table 1. Number of females detected in estrus before and after the 72-h AI and the interval from timed AI to estrus for females in estrus before and after the timed AI.

		d 13	d 15	d 17	
Before:	d				% ^a
Heifers	-2	0	0	0	(0%)
	-1	0	0	0	(0%)
		0/ 51 (0%)	0/ 47 (0%)	0/ 51 (0%)	
Cows	-2	1	0	0	(1%)
	-1	6	1	0	(2%)
		7/112 ^b (6%)	1/143 ^c (1%)	0/144 ^c (0%)	
After:	d				
Heifers	+1	7	8	3	(12%)
	+2	8	4	4	(11%)
	+3	4	6	2	(8%)
	+4	2	3	4	(6%)
	+5	0	0	0	(0%)
	+6	0	0	0	(0%)
	+7	0	0	0	(0%)
		21/ 51 ^{b,c} (41%)	21/ 47 ^b (45%)	13/ 51 ^c (26%)	
Cows	+1	9	10	13	(8%)
	+2	15	11	20	(12%)
	+3	4	8	12	(6%)
	+4	2	5	5	(3%)
	+5	3	1	4	(2%)
	+6	1	2	2	(1%)
	+7	1	0	3	(1%)
		35/112 ^{b,c} (31%)	37/143 ^b (26%)	59/144 ^c (41%)	

^aPercentage of all females (all three groups combined) in estrus on a given day.

^{b,c}Values with different superscripts differ (P < .05).

Table 2. Number of females with corpora lutea immediately before and 3 days after PGF_{2α} treatment^d and progesterone concentrations for females with corpora lutea (CL) before PGF_{2α}.

	Interval from MGA to PGF _{2α}		
	d 13	d 15	d 17
Number of females with CL before PGF _{2α} treatment ^e			
Heifers	36/ 50 (72%)	22/ 42 (52%)	36/ 49 (74%)
Cows	57/112 ^a (51%)	93/140 ^b (66%)	84/136 ^{a,b} (62%)
Progesterone concentrations (ng/ml) for females with CL before PGF _{2α} treatment			
Heifers	4.51 ± .37	5.63 ± .50	5.14 ± .40
Cows	3.11 ± .28 ^a	4.27 ± .26 ^b	5.44 ± .28 ^c
Number of females with CL that regressed ^f by timed AI ^g			
Heifers	29/ 36 ^a (81%)	20/ 22 ^{a,b} (91%)	35/ 36 ^b (97%)
Cows	52/ 57 ^a (91%)	90/ 93 ^a (97%)	66/ 84 ^b (79%)
Number of females with progesterone concentrations < 1.0 ng/ml at the timed AI			
Heifers	42/ 50 (84%)	36/ 42 (86%)	44/ 49 (90%)
Cows	96/112 ^a (86%)	137/140 ^b (98%)	110/136 ^a (81%)

^{a,b,c}Values with different superscripts differ (P < .05).

^dPresence and absence of CL was based on progesterone concentrations. Females that had progesterone concentrations ≥ 1.5 ng/ml were considered to have CL.

^eBlood was collected immediately before PGF_{2α} treatment.

^fFemales that had progesterone concentrations < 1.0 ng/ml on the d of AI were considered to have CL that regressed.

^gPercent of CL that regressed to PGF_{2α} treatment; number of females with CL that regressed ÷ number with females with CL at PGF_{2α} treatment.

Table 3. Pregnancy rates of females administered MGA and PGF_{2α} for estrus synchronization with intervals of 13, 15, and 17 days between the last day of MGA feeding and PGF_{2α} treatment.

	d 13	d 15	d 17
Timed AI:			
Heifers	10/ 51 ^a (20%)	9/ 47 ^a (19%)	22/ 51 ^b (43%)
Cows	36/112 ^{a,b} (32%)	61/143 ^a (43%)	45/144 ^b (31%)
Preceding Insemination:			
Heifers	0/ 0 (0%)	0/ 0 (0%)	0/ 0 (0%)
Cows	5/ 7 (71%)	0/ 1 (0%)	0/ 0 (0%)
Succeeding Insemination ^c :			
Heifers	8/ 19 (42%)	13/18 (72%)	4/ 9 (44%)
Cows	19/ 27 (70%)	21/29 (72%)	31/ 52 (60%)
Synchronized Inseminations ^d :			
Heifers	18/ 51 (35%)	22/ 47 (47%)	26/ 51 (51%)
Cows	55/112 (49%)	82/143 (57%)	76/144 (53%)

^{a,b}Values with different superscripts differ (P < .05).

^cDays 1, 2, and 3 after the timed AI.

^dPregnancies from the 72-h AI and the succeeding inseminations combined.

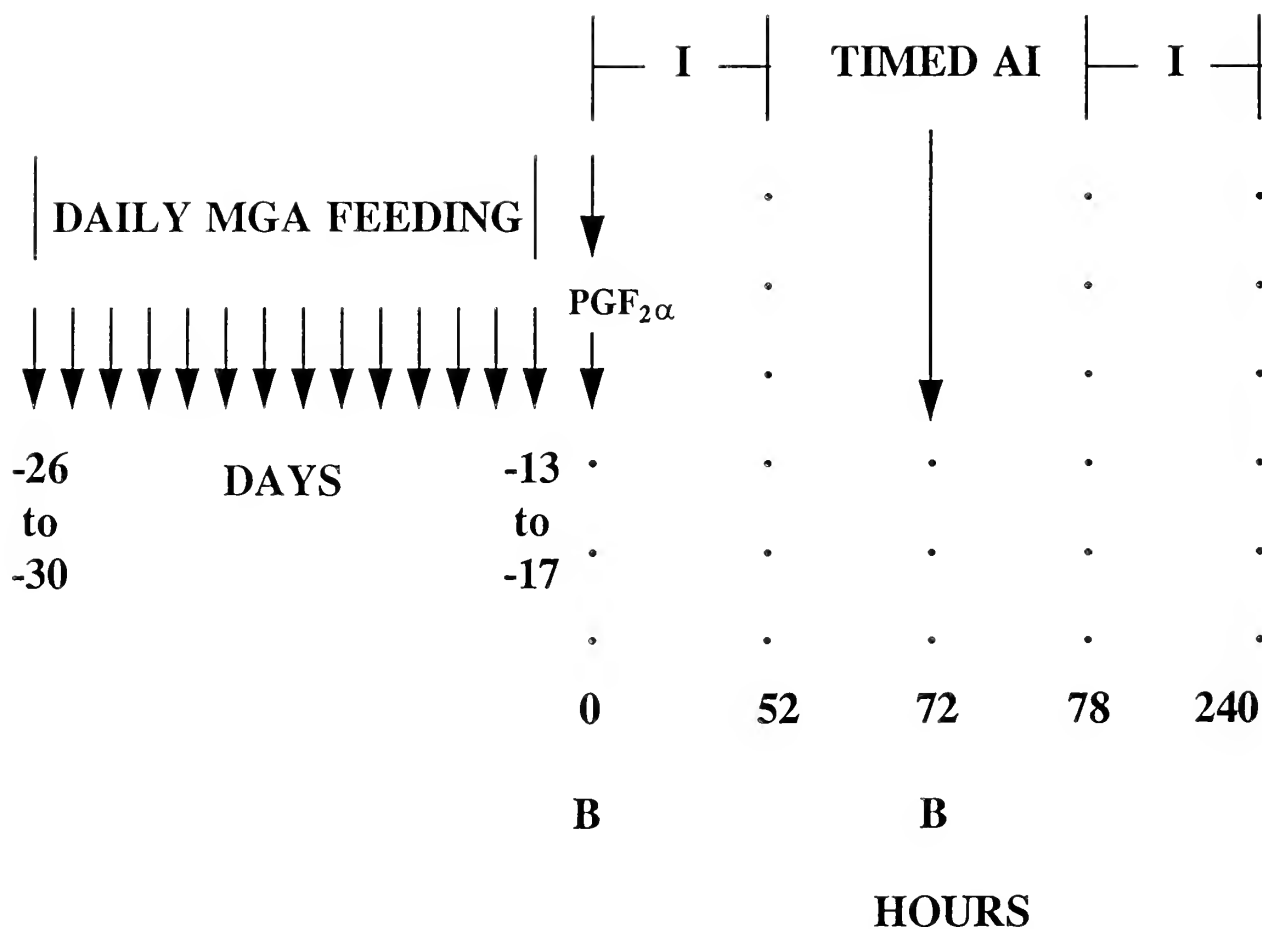


Fig. 1. Treatments and insemination times for females administered MGA and PGF_{2α} for estrus synchronization. MGA was fed daily for 14 d and the interval from the last d of MGA feeding to PGF_{2α} treatment was 13, 15, and 17 d for the three groups of females. Females were also bled immediately before PGF_{2α} treatment and immediately before the 72-h AI.

EFFECT OF PROSTAGLANDIN $F_{2\alpha}$ ADMINISTERED BEFORE ESTROUS SYNCHRONIZATION WITH NORGESTOMET AND ESTRADIOL VALERATE ON CALVING RATES OF BEEF COWS

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SUMMARY

Three experiments were conducted to evaluate the effects of prostaglandin $F_{2\alpha}$ treatments 5, 9, and 14 d before Syncro-Mate B[®] on calving rates of 1072 beef cows from inseminations at a pre-set time. The administration of prostaglandin $F_{2\alpha}$ 5 d before Syncro-Mate B[®] decreased ($P < .01$) calving rates. This reduction was associated with lower ($P < .05$) calving rates in cows administered Syncro-Mate B[®] in the first half of the estrous cycle. Calving rates were unaffected in cows administered prostaglandin $F_{2\alpha}$ 9 d before Syncro-Mate B[®]. The administration of prostaglandin $F_{2\alpha}$ 14 d before Syncro-Mate B[®] reduced ($P < .05$) calving rates in previously anestrous cows. In summary, prostaglandin $F_{2\alpha}$ should not be administered to postpartum cows 5 to 14 d before Syncro-Mate B[®] synchronization.

INTRODUCTION

Estrous synchronization programs can be separated into two categories: luteolytic agents or combinations of progestins and luteolytic/anti-luteotropic agents. Programs using luteolytic agents ($PGF_{2\alpha}$) hasten estrus in females with mature corpora lutea (CL; \geq d 5 of the estrous cycle; Lauderdale et al., 1974). A major problem with $PGF_{2\alpha}$ is the variability of the interval from injection to estrus (Odde, 1990).

Programs utilizing progestins and luteolytic/anti-luteotropic agents, such as Syncro-Mate B[®] (SMB; Kesler and Favero, 1995), have more predictable intervals from progestin withdrawal to estrus allowing for a single timed artificial insemination (Hixon et al., 1981; Odde, 1990). Pregnancy rates of cattle synchronized with SMB, however, have been variable (Kesler and Favero, 1995).

Although not consistent with all published data (Pratt et al., 1991; Fanning et al., 1992; Burns et al., 1993), Brink and Kiracofe (1988) reported higher pregnancy rates in females administered SMB during the first half of the estrous cycle. Therefore, we hypothesized that the administration of $PGF_{2\alpha}$ 5 d before SMB would enhance SMB pregnancy rates because the majority of the cows that had estrous cycles would be in the first half of the estrous cycle at the time of SMB treatment.

MATERIALS AND METHODS

Three experiments were conducted over three consecutive years (1992, 1993, and 1994) with cross-bred beef cows from the Dixon Springs Agricultural Center (DSAC). All cows were 3 to 12 years old, had calved 42 to 112 d before the first insemination, were suckling calves, and were administered the SMB estrous synchronization procedure (Rhone Merieux, Inc., Athens, GA).

This procedure consisted of an intramuscular injection of norgestomet (3.0 mg) and estradiol valerate (5.0 mg) in sesame oil and benzyl alcohol and an ear implant containing 6.0 mg of norgestomet. The implant was subcutaneously inserted into the convex surface of the ear. After 9 d the norgestomet implants were removed. Any cows that lost their implants were removed from the study. Approximately 48 h after removal of the norgestomet implants, all cows were artificially inseminated (AI) with commercially available frozen semen by two technicians. Multiple sires were used and service sire selection was made before the timed AI and before the cows were completely randomly allotted to treatment groups. All cows had ad libitum access to fescue hay, pasture, and a complete vitamin and mineral mixture. The cows were maintained on pasture for the duration of the experiments (about 10 mo) except when treatments were imposed. Estrous synchronization and AI were conducted during March and April.

In Exp. 1, 133 cows were not treated with $\text{PGF}_{2\alpha}$ to serve as a control group and 131 cows were administered 25 mg of $\text{PGF}_{2\alpha}$ (Lutalyse®; Pharmacia and Upjohn, Inc., Kalamazoo, MI) 5 d before SMB treatment. In Exp. 2, 247 cows were not treated with $\text{PGF}_{2\alpha}$ (controls) and 235 cows were administered $\text{PGF}_{2\alpha}$ 9 d before SMB treatment. In Exp. 3, 169 cows were used as controls and 157 cows were administered $\text{PGF}_{2\alpha}$ 14 d before SMB treatment. The cows were administered $\text{PGF}_{2\alpha}$ 5, 9, or 14 d before SMB so that the cows which had resumed estrous cycles after calving would be on d 2 to 9, d 6 to 13, and d 11 to 18 of their estrous cycle, respectively, when administered SMB (Table 1). The $\text{PGF}_{2\alpha}$ lyses the CL 5 d or greater after estrus and the majority of these females exhibit estrus 2 to 3 d after $\text{PGF}_{2\alpha}$ treatment (Lauderdale et al., 1974). Cows 0 to 4 d after estrus would not respond to the $\text{PGF}_{2\alpha}$ treatment and would continue to develop CL. Cows were completely randomly assigned to one of two groups (no $\text{PGF}_{2\alpha}$ or $\text{PGF}_{2\alpha}$ treatment) immediately before the time of $\text{PGF}_{2\alpha}$ treatment. Clean-up bulls of similar genotype to the AI bulls were included with the cows beginning 22 d after the timed AI.

Blood was collected from all cows 11 d before and at the time of $\text{PGF}_{2\alpha}$ treatment and again at the SMB treatment to determine whether the cows were anestrus or had resumed estrous cycles before SMB synchronization (Table 1). Blood was collected via jugular venipuncture into syringes and immediately placed in an ice water bath and held until centrifugation within 6 h after collection (Wiseman et al., 1983). Serum was collected by centrifugation at 1,000 x g for 15 m at 4°C. Serum samples were individually stored in 4-mL vials at -20°C until assayed. Progesterone concentrations were determined by a validated enzyme immunoabsorbant assay (ELISA) (Kesler et al., 1990).

If progesterone concentrations were 1.5 ng/mL or greater in any one of the three blood samples collected before SMB treatment, cows were considered to have resumed estrous cycles following parturition. If progesterone concentrations in all three of the blood samples were less than 1.5 ng/mL, cows were considered anestrus.

In Exp. 1, cows were assigned to a stage of the estrous cycle on the basis of the three progesterone concentrations (on d -16, -5, and 0) before SMB treatment. This assignment was based on the following assumptions: 1) that all cows had 18- to 24-d estrous cycles, 2) that progesterone concentrations increased to 1.5 ng/mL or greater (H) on d 6 of the estrous cycle, and 3) that progesterone decreased to less than 1.5 ng/mL (L) 3 d before estrus. Therefore, cows with the

sequences of HLL, HHL, and HLH on d -16, -5, and 0 (time of SMB treatment) were considered to be on d 0 to 10 (first half) of the estrous cycle. Cows with HHH, LHL, and LHH were considered to be on d 11 to 20 (second half) of the estrous cycle. Cows with the LLL sequence were considered to be anestrus as previously defined. Assumptions 2 and 3 were validated in our laboratory using the same progesterone ELISA as used in these experiments (D. J. Kesler, unpublished data).

Calving rates and estimated date of conception were determined the following calving season. Since calving rates reflect pregnancy rates (Vaillancourt et al., 1979), although they may be 5 to 10% lower due to spontaneous abortions (Bondurant, 1991), it was chosen because of iatrogenic abortions associated with per rectum pregnancy determination (Franco et al., 1987) and because per rectum pregnancy examinations (at 40 to 45 d post-breeding) mis-diagnose 4.2% of the pregnant cows (Alexander et al., 1995). Cows were considered to have conceived to the timed AI if they calved 283 ± 11 d after the timed AI. In previous years, 99% of the cows with similar genotype and ages inseminated with bulls of similar genotype calved 283 ± 11 d after insemination. Further, since clean-up bulls were not included with the cows until 22 d after the timed AI, little ($\approx 1\%$) overlap between synchronized pregnancies and clean-up pregnancies exist. Analysis (by analysis of variance [Hicks, 1964]) following randomization demonstrated that cow age, postpartum interval, AI technician, and service sire were similar ($P > .25$) between groups for all three experiments. Calving data were analyzed using the categorical data model (CATMOD) procedure of SAS (1988) which analyzes data that can be represented by a two-dimensional contingency table. Estrous cycle resumption status (cyclic or anestrus) and $\text{PGF}_{2\alpha}$ treatment (none or $\text{PGF}_{2\alpha}$) were included as the main effects in the model. Resumption of estrous cycles, calving rates among treatments for the control cows that were anestrus and for the cows that had estrous cycles, and calving rates among the anestrus cows, the cows in the first half, and the cows in the second half of the estrous cycle were analyzed by Chi-square analysis (Cochran and Cox, 1957).

RESULTS AND DISCUSSION

Although the pre-SMB treatment estrous cycle resumption status was similar between treatments (no $\text{PGF}_{2\alpha}$ and $\text{PGF}_{2\alpha}$) within experiments, a difference ($P < .01$) existed in the number of cows that had resumed estrous cycles after calving among experiments: 70, 30, and 7 percent of the cows had estrous cycles before SMB treatment in Exp. 1, 2, and 3, respectively. This was not due to the $\text{PGF}_{2\alpha}$ treatments since the same trend was apparent in both the control and the $\text{PGF}_{2\alpha}$ treated cows.

Calving rates were not effected ($P > .25$) by estrous cycle resumption status in Exp. 1 and 2. In Exp. 3, however, there tended ($P = .08$) to be a higher calving rate in the cows with estrous cycles than in the anestrus cows, although only a small number of cows with estrous cycles were available. It has previously demonstrated that SMB will hasten ovarian cycles in anestrus cows (Kesler and Favero, 1996), however, since all cows in these experiments were administered SMB, its effect in inducing estrous cycles in anestrus cows was not assessed. Calving rates were similar

($P > .25$) among experiments for control cows with estrous cycles, however, differences were noted among experiments for the control anestrous cows (Table 2).

In contrast to our hypothesis, calving rates tended to be lower ($P < .09$) for the cows that had estrous cycles and were administered $\text{PGF}_{2\alpha}$ 5 d before SMB treatment than for the cows that were not administered $\text{PGF}_{2\alpha}$ (Exp. 1; Table 2). Overall, cows in Exp. 1, regardless of whether they had estrous cycles, had lower ($P < .01$) calving rates if $\text{PGF}_{2\alpha}$ was administered 5 d before SMB treatment. Administration of $\text{PGF}_{2\alpha}$ 9 d before SMB treatment, however, had no effect ($P > .10$) on calving rates of both the anestrous cows and the cows that had estrous cycles (Exp. 2). Prostaglandin $\text{F}_{2\alpha}$ treatment 14 d before SMB treatment decreased ($P < .05$) the calving rates of the anestrous cows (Exp. 3).

We further evaluated the data in Exp. 1 by classifying the cows that had resumed estrous cycles after parturition into one of two stages of the estrous cycle. This classification was based on the presence or absence of progesterone concentration in the three blood samples collected before SMB treatment as described earlier. Because $\text{PGF}_{2\alpha}$ lyses the CL 5 d or greater after estrus, the majority of those females should be on d 2 to 3 of a new estrous cycle at the time of SMB treatment. Females on d 0 to 4 of the estrous cycle and not responding to the $\text{PGF}_{2\alpha}$ will be on d 5 to 9 of the estrous cycle at the time of SMB treatment. Therefore, the majority of females that had resumed estrous cycles should be in the first half of the estrous cycle at the time of SMB treatment. Data in Table 3 show that 36 of the 95 (38%) control cows were in the first half of the estrous cycle at the time of SMB treatment. In contrast, 71 of the 91 (78%) cows that had estrous cycles and administered $\text{PGF}_{2\alpha}$ were in the first half of the estrous cycle at the time of SMB treatment, which is higher ($P < .01$) than in the control cows because of $\text{PGF}_{2\alpha}$'s luteolytic effect (Lauderdale et al., 1974). Calving rates for both the control and $\text{PGF}_{2\alpha}$ treated cows were similar within stage of the estrous cycle and demonstrate that cows treated with SMB during the first half of the estrous cycle had lower ($P < .05$) calving rates than cows in the second half of the estrous cycle (Table 3). This would explain the decrease in calving rates in the $\text{PGF}_{2\alpha}$ treated cows that had estrous cycles but is in contradiction with our hypothesis and data published by Brink and Kiracofe (1988).

It is not clear why our data differ from that of Brink and Kiracofe (1988). However, Pratt et al. (1991), Fanning et al. (1992), and Burns et al. (1993) have demonstrated that SMB is ineffective in regressing CL in 42 to 48% of the females treated during metestrus; therefore, they would not be in synchrony for a timed breeding. Exp. 2 included cows on d 6 to 7 of the estrous cycle when administered SMB (Table 1) and calving rates were not adversely effected. However, in Exp. 1, cows were also on d 2 to 3 of the estrous cycle (Table 1) which might explain the decreased calving rates observed.

The decrease in calving rates of the anestrous cows administered $\text{PGF}_{2\alpha}$ 14 d before SMB was unexpected since there was no shift in their stage of the estrous cycle. However, $\text{PGF}_{2\alpha}$ will induce a rise in luteinizing hormone concentrations in anestrous cows (D.J. Kesler, unpublished data) and pregnancy has been established in previously anestrous cows after two injections of $\text{PGF}_{2\alpha}$ (Roche, 1976; Troxel et al., 1983). Therefore, after $\text{PGF}_{2\alpha}$ treatment, some of the previously anestrous cows may have ovulated and after a short estrous cycle of 8 to 10 d (Troxel

and Kesler, 1984) the cows were on d 2 to 3 of their second postpartum estrous cycle at the time of SMB treatment. This would be the same stage of the estrous cycle that was associated with decreased calving rates in Exp. 1.

Since very few cows had resumed estrous cycles before SMB treatment in Exp. 3, cows in the second half of the estrous cycle at the time of SMB treatment could not be evaluated. However, based on data from Exp. 1, even if all 326 of the cows in Exp. 3 had estrous cycles, the calving rate would have been expected to be similar to the 36% calving rate observed for the control cows in Exp. 1 and 2. Also, since the calving rates were reduced ($P < .05$) for the anestrous cows, a reason would not exist for using the $\text{PGF}_{2\alpha}$ 5 to 14 d before SMB treatment in postpartum cows.

IMPLICATIONS

Administration of $\text{PGF}_{2\alpha}$ 5 d before SMB reduced calving rates from synchronized timed inseminations. Prostaglandin $\text{F}_{2\alpha}$ administered 5 d before SMB caused more females to be in the first half of the estrous cycle and calving rates in the first half of the estrous cycle were lower for both control and $\text{PGF}_{2\alpha}$ treated cows. Administration of $\text{PGF}_{2\alpha}$ 9 d before SMB treatment had no effect on calving rates whereas administration of $\text{PGF}_{2\alpha}$ 14 d before SMB treatment decreased calving rates in previously anestrous cows. Therefore, $\text{PGF}_{2\alpha}$ should not be administered before SMB treatment.

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REFERENCES

- Alexander, B. M., M. S. Johnson, R. O. Guardia, W. L. Van de Graaf, P. L. Senger, and R. G. Sasser. 1995. Embryonic loss from 30 to 60 days post breeding and the effect on palpation per rectum on pregnancy. *Theriogenology* 43:551.
- Brink, J. T. and G. H. Kiracofe. 1988. Effect of estrous cycle stage at Syncro-Mate B treatment on conception and time to estrus in cattle. *Theriogenology* 29:513.
- Bondurant, R. H. 1991. Influence of infectious diseases on reproduction. In: P. T. Cupps (Ed.) *Reproduction in Domestic Animals*. Academic Press, Inc., San Diego, CA, p. 637.
- Burns, P. D., J. C. Spitzer, W. C. Bridges, D. M. Henricks, and B. B. Plyler. 1993. Effects of metestrous administration of a norgestomet implant and injection of norgestomet and estradiol valerate on luteinizing hormone and development and function of CL in suckled beef cows. *J. Anim. Sci.* 71:983.

- Cochran, W. G. and G. M. Cox. 1957. *Experimental Design* (2nd Ed.). John Wiley & Sons, New York.
- Fanning, M. D., J. C. Spitzer, G. L. Burns, and B. B. Plyler. 1992. Luteal function and reproductive response in suckled beef cows after metestrus administration of a norgestomet implant and injection of estradiol valerate with various dosages of injectable norgestomet. *J. Anim. Sci.* 70:1352.
- Franco, O. J., M. Drost, M. J. Thatcher, V. M. Shille, and W. W. Thatcher. 1987. Fetal survival in the cow after pregnancy diagnosis by palpation per rectum. *Theriogenology* 27:631.
- Hicks, C.R. 1964. *Fundamental Concepts in the Design of Experiments*. Holt, Rinehart, and Winston, Inc., New York.
- Hixon, D. L., D. J. Kesler, T. R. Troxel, D. L. Vincent, and B. S. Wiseman. 1981. Reproductive hormone secretions and first service conception rate subsequent to ovulation control with Syncro-Mate B. *Theriogenology* 16:219.
- Kesler, D. J., H. Khazali, and R. J. Favero. 1990. Quantification of steroids via a polymer linked second antibody immunoassay: methods of linking anti-rabbit IgG to poly(styrene). In: C. G. Gebelien and R. L. Dunn (Ed.) *Progress in Biomedical Polymers*. Plenum Publishing, New York, p. 157.
- Kesler, D. J. and R. J. Favero. 1995. Estrus synchronization in beef females with norgestomet and estradiol valerate. Part 1: mechanisms of action. *Agri-Practice* 16:6.
- Kesler, D. J. and R. J. Favero. 1996. Estrus synchronization in beef females with norgestomet and estradiol valerate. Part 2: factors limiting and enhancing efficacy. *Agri-Practice* 17:12.
- Lauderdale, J. W., B. E. Sequin, J. N. Stellflug, J. R. Chenault, W. W. Thatcher, C. K. Vincent and A. F. Loyancano. 1974. Fertility of cattle following PGF_{2α} injection. *J. Anim. Sci.* 38:964.
- Odde, K. B. 1990. A review of synchronization of estrus in postpartum cattle. *J. Anim. Sci.* 68:817.
- Pratt, S. L., J. C. Spitzer, G. L. Burns, and B. B. Plyler. 1991. Luteal function, estrous response and pregnancy rate after treatment with norgestomet and various dosages of estradiol valerate in suckled cows. *J. Anim. Sci.* 69:2721.
- Roche, J. F. 1976. Fertility in cows after treatment with a prostaglandin analogue with or without progesterone. *J. Reprod. Fertil.* 46:341.

- SAS Institute, Inc. 1988. SAS/STAT® User's Guide (Release 6.03). SAS Institute Inc., Cary, NC.
- Troxel, T. R. and D. J. Kesler. 1984. Ability of indomethacin to alter prostaglandin metabolite concentrations and to enhance the function of corpora lutea induced in postpartum suckled beef cows. *J. Anim. Sci.* 59:177.
- Troxel, T. R., G. F. Cmarik, R. S. Ott, T. F. Lock, and D. J. Kesler. 1983. The effect of method of GnRH administration and short-term calf removal on ovarian function and reproductive performance in postpartum suckled beef cows administered PGF_{2α} for estrous synchronization. *Theriogenology* 20:417.
- Wiseman, B. S., D. L. Vincent, P. J. Thomford, N. S. Scheffrahn, G. F. Sargent, and D. J. Kesler. 1983. Changes in porcine, ovine, bovine and equine blood progesterone concentrations between collection and centrifugation. *Anim. Reprod. Sci.* 5:157.
- Vaillancourt, D., C. J. Bierschwal, D. Ogwu, R. G. Elmore, C. E. Martin, A. J. Sharp, and R. S. Youngquist. 1979. Correlation between pregnancy diagnosis by membrane slip and embryonic mortality. *J. Am. Vet. Med. Assoc.* 175:466.

Table 1. Schedule of treatments and blood collections by treatments.

Activity	Treatments ^a , d		
	- 5	- 9	- 14
Blood collection, d	- 16	- 20	- 25
Blood collection & PGF _{2α} ^b treatment, d	- 5	- 9	- 14
Blood collection & SMB ^c treatment, d	0	0	0
Implant removal, d	9	9	9
AI, d	11	11	11
Day of the estrous cycle at SMB treatment ^d :			
day 5 + CL ^e , d	2-3	6- 7	11-12
day 0 to 4 CL ^e , d	5-9	9-13	14-18
Stage of the estrous cycle ^f	First	First & Second	Second

^aGroups were based on the interval between PGF_{2α} and SMB treatments: 5, 9, or 14 days.

^bProstaglandin F_{2α} (25 mg of Lutalyse®).

^cSyncro-Mate B®.

^dDay of the estrous cycle at SMB was determined for cows that had estrous cycles as described in the materials and methods.

^eAt the time of PGF_{2α} treatment.

^fCows were classified as either in the first or second half of the estrous cycle as described in the materials and methods.

Table 2. Calving rates of beef cows administered PGF_{2α} before estrous synchronization using Syncro-Mate B®.

	Treatment ^a , d		
	5	9	14
Total number	264	482	326
Estrous cycle status:			
Anestrus, %	30	70	93
Estrous cycles, %	70 ^x	30 ^y	7 ^z
Calving rates			
Anestrus:			
Control (%)	10/ 38 (26) ^{x,y}	62/183 (34) ^x	25/158 [*] (16) ^y
PGF _{2α} (%)	9/ 40 (23)	53/153 (35)	12/144 [*] (8)
Estrous cycles (%):			
Control (%)	34/ 95 [†] (36) ^x	23/ 64 (36) ^x	3/ 11 (27) ^x
PGF _{2α} (%)	22/ 91 [†] (23)	26/ 82 (32)	3/ 13 (23)
Combined:			
Control (%)	44/133 ^{**} (33)	85/247 (34)	28/169 [*] (17)
PGF _{2α} (%)	31/131 ^{**} (24)	79/235 (34)	15/157 [*] (10)

^aExp. 1 = 5 d, Exp. 2 = 9 d, and Exp. 3 = 14 d intervals from PGF_{2α} to SMB.

[†] P = .09

^{*} P < .05

^{**} P < .01

^{x,y,z}Values with different superscripts within rows differ (P < .01).

Table 3. Calving rates of beef cows administered PGF_{2α} 5 d before Syncro-Mate B® based on the estimated stage of the estrous cycle^a at the time of Syncro-Mate B® treatment (Exp. 1).

	Treatment		
	Control	PGF _{2α}	Combined
Anestrus (%)	10/38 (26)	9/40 (23)	19/ 78 (24) ^y
Estrous cycle:			
First half (%)	8/36 (22)	14/71 (20)	22/107 (21) ^y
Second half (%)	27/59 (46)	8/20 (40)	35/ 79 (44) ^z

^aCows were assigned to first half and second half of the estrous cycle based on progesterone concentrations of blood samples collected on d -16, -5, and 0 (time of SMB treatment) as described in the materials and methods.

^{y,z}Means within a column with different superscripts differ (P < .05).

NORGESTOMET IMPLANTATION AFTER INSEMINATION ENHANCES FIRST SERVICE FERTILITY, HASTENS FERTILITY POSTPARTUM, AND SYNCHRONIZES A SECOND ESTRUS IN BEEF FEMALES

D. J. Kesler, D. B. Faulkner, J. A. Martin, and T. G. Nash

SUMMARY

Administration of norgestomet during pregnancy had no detrimental effects on established pregnancy but synchronized the return estrus of non-pregnant females. In addition, administration of norgestomet implants after insemination enhanced fertility in synchronized females when herdmates not administered norgestomet after insemination had low pregnancy rates. When administered to early postpartum cows, pregnancy was reestablished earlier postpartum. Although most data were collected with females implanted with norgestomet/silicone implants, data from this study would suggest that norgestomet/hydron implants, the Syncro-Mate B implant, may be efficacious although some females exhibited estrus with the norgestomet/hydron implants *in situ*. Additional results from this study may suggest that females that exhibit estrus with norgestomet/hydron implants *in situ*, may become pregnant to that estrus if implants are removed upon the detection of estrus and AI is done by the am/pm rule.

INTRODUCTION

Current commercial estrus synchronization procedures, Syncro-Mate B® (SMB; Kesler and Favero, 1996) and prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) and its analogues (Odde, 1990), effectively synchronize estrus and ovulation in beef cattle and dairy heifers, however, these products can be used to synchronize only one estrus and ovulation. Since pregnancy results are variable when females are synchronized with these products, procedures that increase the number of females that become pregnant to artificial insemination (AI) are needed (Ghallab et al., 1984). Favero et al. (1993 and 1995) administered norgestomet implants to beef females after a synchronized AI and reported an increase in the number of pregnancies resulting from AI. They, however, used norgestomet/silicone implants. The objective of this study was to determine if the commercial norgestomet/hydron implant, the SMB implant, could be used as effectively as the norgestomet/silicone implants to increase the number of pregnancies resulting from AI. An additional objective of this publication was to summarize the effects of post-insemination norgestomet treatment from other studies.

MATERIALS AND METHODS

Thirty-eight beef heifers and 45 postpartum suckled beef cows from the University of Illinois Beef Unit, Urbana, IL were included in this study. Females (29 heifers and 38 cows) were administered SMB norgestomet implants approximately 12 days after a synchronized estrus and insemination. The norgestomet implants were left *in situ* for 9 days. The other 9 heifers and 7 cows were not implanted and served as controls. Beginning at the time of norgestomet implantation, females were observed at least twice daily for estrus. Three females were detected in estrus with implants *in situ*. In these females, upon the first detection of estrus the implants

were removed and they were artificially inseminated by the am/pm rule. Females detected in estrus after implant removal were bred via the am/pm rule. Five days after removal of the second implant bulls were included with the females for follow-up breeding. Forty-six and 76 days after the first timed AI, pregnancy was determined per rectum.

RESULTS AND DISCUSSION

Previous post-insemination norgestomet treatment studies (Favero et al., 1993; Favero et al., 1995) were conducted with norgestomet/silicone implants. Results from those studies (Favero et al., 1993; Favero et al., 1995) are summarized in Tables 1 and 2. Results from this study are reported in Table 3.

When norgestomet/silicone implants were used, few females (3% of the heifers and cows combined) were detected in estrus with implants in situ. In contrast, 43% of the untreated females were detected in estrus during the same period of time. When norgestomet/hydron implants were used, although only 9% of the treated females were detected in estrus with implants in situ, the number of females in estrus was similar ($P > .25$) to the number of untreated females in estrus during the same period of time. It would appear that either the expression of estrus for the non-pregnant females or the detection of estrus was sub-normal in this study or there were too few untreated females to determine an accurate percentage of females in estrus during this time period. The three implanted females that were observed in estrus were in estrus on 6, 6, and 9 days post-implantation; 18, 18, and 21 days after the first AI. Previously published data (Kesler et al., 1995) has demonstrated that during the second half of the 9 day implantation period more norgestomet diffuses from the norgestomet/silicone implants than from the norgestomet/hydron implants in situ. Machado and Kesler (1996) have demonstrated that diffusion of 137 μg or greater of norgestomet per day was needed to suppress estrus in 100% of the treated females. However, lower concentrations of norgestomet (86 to 135 μg) tended to reduce the number of females expressing estrus as compared to untreated females treated similarly (Machado and Kesler, 1996). It may be that less than the minimal required daily dosage of norgestomet for 100% estrus suppression diffused from the norgestomet/hydron implants in this study.

After removal of the norgestomet/silicone implants, the non-pregnant females exhibited a synchronized estrus (Table 1). Overall, 84% of the females that were detected in estrus after removal of the norgestomet/silicone implant were in estrus in a three day period. Similarly, 79% of the norgestomet/hydron implanted females had a synchronized estrus after removal of the implants. However, only 74% of the non-pregnant females in the norgestomet/silicone studies (Table 1) and 54% of the non-pregnant females in this study (with norgestomet/hydron implants) were detected in estrus (Table 3). In a larger study, Domatob et al. (1996) evaluated three methods of determining breeding status of the females. In that study (that used norgestomet/silicone implants), although all three methods (detection of estrus, progesterone concentrations [at the time of implant removal], and anterior vagina electrical resistance values [48 hours after implant removal]) were equivalent, only 74% of the non-pregnant females were considered to be in estrus. Therefore, although the percentage of non-pregnant females detected in estrus in the norgestomet/silicone studies (Favero et al., 1993; Favero et al., 1995; Domatob et al., 1996) were similar, the results of this study (with norgestomet/hydron implants) were lower

suggesting that the detection and/or the expression of estrus was sub-normal in this study. It was also noteworthy that a significant percentage of females not pregnant to the first AI were not detected in estrus 21 to 23 days later. Since these females have elevated progesterone concentrations (Domatob et al., 1996) it may be that either they are in fact pregnant and pregnancies are later lost (Bondurant 1991; Silvia, 1994) or they have an estrous cycle length greater than normally observed (Favero et al., 1993).

Our studies are by no means the first studies where progestins have been administered post-insemination. The objective of many of the other published research was to enhance the pregnancy rate to the previous insemination (Herrick, 1953; Johnson et al., 1958; Robinson et al., 1989; Stevenson and Mee, 1991; VanCleeff et al., 1991; Wiltbank et al., 1956). Most of the older studies were focusing on repeat breeder cows. Results from our norgestomet/silicone implant studies demonstrated that post-insemination norgestomet enhanced the first service pregnancy rate in heifers but not in cows (Favero et al., 1993; Favero et al., 1995). In those studies the pregnancy rate in the untreated heifers was low (21% first service pregnancy rate) but not in the untreated cows (49% first service pregnancy rate). Therefore, rather than just having an effect on heifers, it may be that the benefit occurred when the pregnancy rate of the non-norgestomet treated females was low. In fact, the pregnancy rates in the norgestomet/silicone implanted heifers (50% first service pregnancy rate) and cows (45% first service pregnancy rate) were similar. First service pregnancy rates for the untreated females in this study were lower than expected and the first service pregnancy rates in the norgestomet/hydron implanted females (48%) were equal to the first service pregnancy rates in the norgestomet/silicone implanted females (46%; Table 2; Favero et al., 1993 and 1995). However, the low first service pregnancy rate in the untreated females in this study was for a small sample of females.

The first service pregnancy rates for the treated and untreated females would suggest that post-insemination norgestomet treatment does not have a detrimental effect on pregnancy. Domatob et al. (1994) and Kesler (1996) have previously demonstrated that norgestomet treatment does not have adverse effects of progesterone secretion by the corpus luteum. However, in these studies only norgestomet was administered by implant delivery. Favero et al. (1993) included the injection component of SMB when implanting norgestomet implants on day 12 post-insemination. When the SMB injection was included, pregnancy rates were reduced. In that study (Favero et al., 1993), the pregnancy rate of the implanted heifers without the injection was 53% vs 5% for the implanted heifers also administered the injection. The SMB injection contains 3 mg of norgestomet and 5 mg of estradiol valerate. We hypothesized that the estradiol valerate is responsible for the detrimental effect on pregnancy rates since Aldrich et al. (1995) observed similar detrimental effects when heifers were administered estradiol benzoate and testosterone propionate implants. The absence of adverse effects of norgestomet in this study (using norgestomet/hydron implants) also demonstrates that a large dosage of norgestomet on a given day did not adversely effect the maintenance of pregnancy. It has previously been demonstrated that the norgestomet/hydron implant releases nearly 1.0 mg of norgestomet on the first day *in situ* (Kesler et al., 1995).

Use of SMB synchronization along with post-insemination norgestomet treatment via silicone implants produced pregnancy rates to AI over a 23 day breeding period of 72% (Table 2; Favero

et al., 1993 and 1995). This is nearly double the number of AI pregnancies resulting from SMB synchronization (Kesler and Favero, 1996). When norgestomet/hydrone implants were used, the pregnancy rate to AI over a 23 day breeding period was 58% but if females open at the end of the breeding season were excluded, with the assumption that they were sterile, the pregnancy rate was 63% (Table 3). These pregnancy rates included the three females that were in estrus with the implants *in situ*. Of those three females, two became pregnant to the breeding that was done after early implant removal and AI via the am/pm rule.

In addition to synchronizing the return estrus of non-pregnant females and enhancing the pregnancy rate of heifers or females that did not respond effectively to the first synchronization, post-insemination norgestomet treatment also hastened fertility in postpartum suckled beef cows (Favero et al., 1995). In that study, although the pregnancy rates for cows < 42 days postpartum at the first insemination were low (27%), the number of AI pregnancies resulting to the two timed inseminations during a 23 day breeding period were equal to the number of AI pregnancies (to two timed inseminations during a 23 day breeding period) for cows > 42 days postpartum at the time of the first service. The calving dates for the next calving season for the early postpartum cows (< 42 days postpartum at the first AI) that became pregnant during the 23 day breeding period was advanced an average of 46 days (319 day calving interval) and some cows became pregnant as early as 19 days postpartum. Further, the calving rate to the second AI of 53% (after two implantation periods) tended to be greater ($P = .11$) than the pregnancy rate of 27% for cows at an equal stage postpartum (33 to 59 days) after only one norgestomet implantation validating the value of norgestomet treatment after the first insemination.

Norgestomet has been demonstrated to mimic three of progesterone's biological activities: 1) suppression of estrus, 2) suppression of the preovulatory luteinizing hormone surge, and 3) maintenance of pregnancy in the absence of ovaries and corpora lutea (Kesler and Favero, 1996). Since norgestomet suppresses estrus, synchronization of a return estrus was expected. Previous data has demonstrated that progestins, including norgestomet, hastens ovarian cycles in heifers and cows (Hixon et al., 1981). Further, if ovulation is not hastened in heifers by one implantation, a second implantation may be effective (Ghallab et al., 1984). In postpartum cows, although the lifespan of corpora lutea resulting from the first postpartum ovulation is generally abbreviated (Kesler et al., 1981) because of uterine prostaglandin secretions (Troxel and Kesler, 1984), norgestomet treatment suppresses prostaglandin concentrations and corpora lutea that develop subsequent to an ovulation hastened with norgestomet has a lifespan of normal duration (Troxel and Kesler, 1984) and is capable of maintaining pregnancy (Troxel et al., 1993).

The mechanism by which post-insemination norgestomet treatment enhances pregnancy in cows with estrous cycles has not been elucidated. However, it may be that norgestomet treatment hastens embryo growth and development as has been observed for progesterone treatment (Garrett et al., 1988a) and hastens synthesis and secretion of the bovine trophoblast protein-1, an antiluteolytic compound synthesized by the embryo (Garrett et al., 1988b; Thatcher et al., 1994). Therefore, a larger percentage of norgestomet treated embryos than untreated embryos may be synthesizing and secreting an antiluteolytic compound around the time of luteal regression in nonpregnant females. Previous data has demonstrated that an unexplainable number of embryos are lost during this period of time (Silvia, 1994).

IMPLICATIONS

Results from this study and the studies of Favero et al. (1993 and 1995) and Domatob et al. (1996) suggest that post-insemination norgestomet treatment may be a procedure to increase the number of pregnancies resulting from AI in herds where the pregnancy rate to the first insemination is marginal and for early postpartum suckled cows. The procedure also allows for timed breeding which removes the need for long term estrus detection. In an evaluation of methods to detect non-pregnant females after post-insemination norgestomet treatment, Domatob et al. (1996) concluded that estrus detection, progesterone concentrations (at the time of implant removal), and anterior vagina electrical resistance values (at the time of the second AI) were equally effective. Since electrical resistance values require the least amount of effort, additional research on the use of electrical resistance for this purpose are needed to confirm these early findings. Further, it also may be useful to administer norgestomet after embryo transfer in recipient females as Salgado and Donaldson (1984) reported for other progestins.

For the three females in this study that exhibited estrus with implants in situ, the implants were removed upon the first detection of estrus. These females were then inseminated approximately 12 hours later. Since 2 of the 3 established pregnancy, this may be a good procedure for such occurrences.

Although, our results suggest that the norgestomet/silicone implant is more effective, the norgestomet/hydrion implant may be of value but caution is advised since the results by Washburn and McCraw (1990) suggested that post-insemination norgestomet treatment with hydrion implants decreased the second service pregnancy rates. However, Washburn and McCraw (1990) implanted the norgestomet/hydrion implants on approximately 15 to 25 days (with a 7 day range to day of treatment) after the first AI. Additional caution is advised as the use of the norgestomet implants as described herein is not approved by the FDA.

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REFERENCES

- Aldrich, SL, Berger, LL, Kesler, DJ, Faulkner, DB, Castree, J: Synovex® H as a prenatal androgenizing agent in beef cattle: effects on the implanted pregnant heifer. *Can. J. Anim. Sci.* 75:543, 1995.
- Bondurant, RH: Influence of infectious diseases on reproduction. In: *Reproduction in Domestic Animals*. Ed. P.T. Cupps, Academic Press, Inc., 1991, pp. 637-656.

- Domatob, FN, Favero, RJ, Ireland, FA, Faulkner, DB, Kesler, DJ: Methods for identifying and inseminating nonpregnant beef females after norgestomet synchronization of the second estrus. *Theriogenology*, In Press.
- Domatob, FN, Machado, R, Ireland, FA, Faulkner, DB, Kesler, DJ: Progesterone and electrical resistance effectively diagnose pregnancy in beef heifers after norgestomet re-synchronization. *J. Anim. Sci.* 72(Suppl. 1):173, 1994.
- Favero, RJ, Faulkner, DB, Kesler, DJ: Norgestomet implants synchronize estrus and enhance fertility in beef heifers subsequent to a timed artificial insemination. *J. Anim. Sci.* 71:2594, 1993.
- Favero, RJ, Faulkner, DB, Nash, TG, Kesler, DJ: Effect of norgestomet after insemination on the calving rate of postpartum suckled beef cows. *J. Anim. Sci.* 73:3230, 1995.
- Garrett, JE, Geisert, RD, Zavy, MT, Gries, LK, Wettemann, RP, Buchanan, DS: Effect of exogenous progesterone on prostaglandin $F_{2\alpha}$ release and the interestrus interval in the bovine. *Prostaglandins* 36:85, 1988a.
- Garrett, JE, Geisert, RD, Zavy, MT, Morgan, GL: Evidence for maternal regulation of early conceptus growth and development in beef cattle. *J. Reprod. Fertil.* 84:437, 1988b.
- Ghallab, AM, Ott, RS, Cmarik, GF, Kesler, DJ, Faulkner, DB, Hixon, JE: Effects of repetitive norgestomet treatments on pregnancy rates in cyclic and anestrus beef heifers. *Theriogenology* 22:67, 1984.
- Herrick, JB: Clinical observations of progesterone therapy in repeat breeding heifers. *Vet. Med.* 48:489, 1953.
- Hixon, DL, Kesler, DJ, Troxel, TR, Vincent, DL, Wiseman, BS: Reproductive hormone secretions and first service conception rates subsequent to ovulation control with Syncro-Mate B. *Theriogenology* 16:207, 1981.
- Johnson, KR, Ross, RH, Fourt, DL: Effect of progesterone administration on reproductive efficiency. *J. Anim. Sci.* 17:386, 1958.
- Kesler, DJ: Remotely-delivered contraception with needle-less norgestomet implants. In: *Contraception in Wildlife Management*. Ed. T.J. Kreeger, U.S. Government Printing Office, Washington, D.C., 1996, In press.
- Kesler, DJ, Favero, RJ: Estrus synchronization in beef females with norgestomet and estradiol valerate. Part 1: Factors limiting and enhancing efficacy. *Agri-Practice* 16:6, 1995.
- Kesler, DJ, Favero, RJ: Estrus synchronization in beef females with norgestomet and estradiol valerate: 2. Factors limiting and enhancing efficacy. *Agri-Practice* 17:12, 1996.

- Kesler, DJ, Favero, RJ, and Troxel, TR: A comparison of hydron and silicone implants in the bovine norgestomet and estradiol valerate estrus synchronization procedure. *Drug Dev. Ind. Pharm.* 21:475, 1995.
- Kesler, DJ, Weston, PG, Pimentel, CA, Troxel, TR, Vincent, DL, Hixon, JE: Diminution of the in vitro response to luteinizing hormone by corpora lutea induced by gonadotropin releasing hormone treatment of postpartum suckled beef cows. *J. Anim. Sci.* 53:749, 1981.
- Machado, R, Kesler, DJ: Efficacy of norethindrone acetate and norgestomet implants in suppressing estrus in beef cows. *Drug Dev. Ind. Pharm.* 22:1211, 1996.
- Odde, KG: A review of synchronization of estrus in postpartum cattle. *J. Anim. Sci.* 68:817, 1990.
- Robinson, NA, Leslie, KE, Walton, JS: Effect of treatment with progesterone on pregnancy rate and plasma concentrations of progesterone in Holstein cows. *J. Dairy Sci.* 72:202, 1989.
- Salgado, R, Donaldson, LE: The effect of intravaginal progesterone on pregnancy rates in cows receiving embryo transfers. *Theriogenology* 21:258 (Abstract), 1984.
- Silvia, WJ: Embryonic mortality and repeat breeder cows. In: *Proceedings of the National Reproduction Symposium*. Ed., E.R. Jordan, Am. Assoc. Bovine Practitioners, 1994, pp. 151-160.
- Stevenson, JS, Mee, MO: Fertility of lactating Holstein cows after post-insemination treatment with a progesterone-releasing intravaginal device (PRID). *J. Dairy Sci.* 74(Suppl. 1):196 (Abstract), 1991.
- Thatcher, WW, Staples, CR, Danet-Desnoyers, G, Oldick, B, Schmitt, EP: Embryo health and mortality in sheep and cattle. *J. Anim. Sci.* 72(Suppl. 3):16, 1994.
- Troxel, TR, Cruz, LC, Ott, RS, Kesler, DJ: Norgestomet and gonadotropin releasing hormone enhance corpus luteum function and fertility of postpartum suckled beef cows. *J. Anim. Sci.* 71:2579, 1993.
- Troxel, TR, Kesler, DJ: The ability of indomethacin to alter prostaglandin metabolite concentrations and to enhance the function of corpora lutea induced in postpartum suckled beef cows. *J. Anim. Sci.* 59:177, 1984.
- Troxel, TR, Kesler, DJ: The effect of progestin and GnRH treatments on ovarian function and reproductive hormone secretions of anestrous postpartum suckled beef cows. *Theriogenology* 21:699, 1984.

- VanCleeff, J., Drost, M., Thatcher, WW: Effects of post-insemination progesterone supplementation on fertility and subsequent estrous responses of dairy heifers. *Theriogenology* 36:795, 1991.
- Washburn, SP, McCraw, RL: Use of norgestomet implants after insemination to synchronize repeat estruses in beef cows. *J. Anim. Sci.* 68(Suppl. 1):13 (Abstract), 1990.
- Wiltbank, JN, Hawk, HW, Kidder, HE, Black, WG, Ulberg, LC, Casida, LE: Effect of progesterone therapy on embryo survival in cows of lowered fertility. *J. Dairy Sci.* 39:496, 1956.

Table 1. The effect of norgestomet administration^a after insemination on estrus of females not becoming pregnant to the first synchronized insemination.

Item	Control	Norgestomet Treated
Favero et al. (1993) ^b ; Beef heifers:		
During implantation period	16/33 ^j (49%)	1/20 ^k (5%)
After implant removal	23/33 (70%)	15/20 (75%)
Peak 3 days after implant removal	12/23 ^d (52%)	14/15 ^e (93%)
Favero et al. (1995) ^c ; Beef cows:		
During implantation period	17/43 ^j (40%)	1/56 ^k (2%)
After implant removal	25/43 ^f (58%)	41/56 ^g (73%)
Peak 3 days after implant removal	14/25 ^h (56%)	33/41 ⁱ (81%)
Combined:		
During implantation period	33/76 ^j (43%)	2/76 ^k (3%)
After implant removal	48/76 (63%)	56/76 (74%)
Peak 3 days after implant removal	26/48 ^j (54%)	47/56 ^k (84%)

^aNorgestomet impregnated silicone implants were used.

^bExperiments 1 and 2 combined.

^cExperiment 1.

^{d,e}Groups differed ($P < .05$) for one of the two trials.

^{f,g}Groups tended to differ ($P = .12$).

^{h,i}Groups differed ($P < .05$).

^{j,k}Groups differed ($P < .01$).

Table 2. The effect of norgestomet administration^a after insemination on pregnancy rates of synchronized beef females.

Item	Control	Norgestomet Treated
Favero et al. (1993) ^b ; Beef heifers		
First timed AI	9/ 42 ^c (21%)	20/ 40 ^f (50%)
Second AI	11/ 23 (48%)	9/ 16 (56%)
Cumulative 1st & 2nd AI	20/ 42 ^g (48%)	29/ 40 ^h (73%)
Favero et al. (1995) ^c ; Beef cows		
First timed AI	42/ 85 (49%)	45/101 (45%)
Second AI	14/ 25 (56%)	27/ 41 (66%)
Cumulative 1st & 2nd AI	56/ 85 (66%)	72/101 (71%)
Favero et al. (1995) ^d ; Beef cows < 42 days postpartum		
First timed AI ⁱ	--	8/ 30 ^g (27%)
Second AI ^j	--	9/ 17 (53%)
Cumulative 1st & 2nd AI	--	17/ 30 (57%)
Favero et al. (1995) ^d ; Beef cows > 42 days postpartum		
First timed AI	--	44/ 88 ^h (50%)
Second AI	--	16/ 33 (49%)
Cumulative 1st & 2nd AI	--	60/ 88 (68%)
Beef heifers and cows combined (Favero et al. 1993 & 1995)		
First timed AI	51/127 (40%)	65/141 (46%)
Cumulative 1st & 2nd AI	76/127 ^g (60%)	101/141 ^h (72%)

^aNorgestomet impregnated silicone implants were used.

^bExperiments 1 and 2.

^cExperiment 1.

^dExperiment 2.

^{e,f}Groups differed ($P < .01$).

^{g,h}Groups differed ($P < .05$).

ⁱMean days postpartum to pregnancy for these eight cows that became pregnant was 29.3 days (19 to 41 days).

^jMean days postpartum to pregnancy for these nine cows was 42.0 days (33 to 59 days).

Table 3. Estrus and pregnancy results of beef females administered norgestomet/hydron implants after insemination.

Item	Control	Norgestomet Treated
Estrus ^a :		
During implantation period	1/11 ^b (9 %)	3/35 ^b (9 %)
After implant removal	5/11 (46 %)	19/35 (54 %)
Days 1 & 2 after implant removal	1/ 5 ^c (20 %)	15/19 ^d (79 %)
Pregnant:		
1st AI	5/16 (31 %)	32/67 (48 %)
Cumulative 1st & 2nd AI	8/16 (50 %)	39/67 (58 %)
AI Calves/Calves born	8/16 (50 %)	39/62 (63 %)

^aOnly females that did not become pregnant to the first AI.

^bThe control female was in estrus on day 4 of the implantation period and the treated females were in estrus on days 6, 6, and 9 of the implantation period. All four of these females were cows. In the three norgestomet treated females that were in estrus with the norgestomet implants in situ, the implants were removed and the females were bred by the am/pm rule. Two of the three established pregnancy to that insemination and are included in the cumulative 1st and 2nd AI and the AI calves/calves born sections.

^{c,d}Groups with different superscripts differ ($P < .05$).

SYNCHRONIZATION OF ESTRUS IN BEEF FEMALES WITH THE MELENGESTROL ACETATE/PROSTAGLANDIN $F_{2\alpha}$ PROCEDURE: ESTRUS AND EFFICACY OF 72-HOUR TIMED AI

D. J. Kesler, D. B. Faulkner, T. S. Dyson,
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SUMMARY

This experiment included 38 heifers and 48 cows. All females were fed .5 mg of MGA per d for 14 d and then randomly assigned to receive PGF_{2 α} (25 mg Lutalyse®) 13, 15, and 17 d after the last d of MGA feeding. Females not detected in estrus for the first 52 h after PGF_{2 α} treatment were artificially inseminated at 72 h after PGF_{2 α} . Females detected in estrus the first 52 h and 78 h to 6 d after PGF_{2 α} (3 d period) were artificially inseminated at estrus. Pregnancy was determined per rectum 44 to 47 d after the 72-h AI. Only two of the 86 females (2%) were detected in estrus during the 14 d MGA feeding period. During the interval from the last d of MGA feeding to PGF_{2 α} treatment, 16 of the heifers (42%) and 6 of the cows (13%) were detected in estrus an average of $5.4 \pm .4$ d after the last day of MGA feeding. Estrus response after PGF_{2 α} treatment and pregnancy rates for heifers and cows with 13, 15, and 17 d intervals from MGA to PGF_{2 α} treatment were similar ($P > .10$) and summarized together. Only 5 of the 86 females (6%) were in estrus 1 or 2 d before the 72-h AI while 16 of the 86 females (19%) were in estrus 1 to 3 d after the 72-h AI. Two of the 5 females (40%) in estrus before the 72-h AI became pregnant while 11 of the 16 females (69%) in estrus after the 72-h AI became pregnant. Of the other 65 females, although only 2 were detected in estrus 52 to 78 h after PGF_{2 α} treatment, 25 of the 65 (39%) females with only 72-h AI became pregnant. The combined 6 d synchronized pregnancy rate was 44% (83/86). In summary, acceptable pregnancy rates were obtained in beef heifers and cows synchronized with MGA and PGF_{2 α} and bred by a combined estrus detection (1, 2, 4, 5, and 6 d after PGF_{2 α} treatment) and timed insemination (72 h after PGF_{2 α} treatment) procedure.

INTRODUCTION

One method of synchronizing estrus in cattle involves the concurrent use of a progestin and a luteolysin. Melengestrol acetate (MGA) suppresses estrus and is orally effective in cattle (Zimbelman and Smith, 1966). However, administration beyond the normal lifespan of corpora lutea suppresses fertility of the subsequent estrus (DeBois and Bierschwal, 1970; Beal et al., 1988; Anderson and Day, 1994). Therefore, some researchers have taken the approach of administering MGA for about 14 d followed by the administration of the luteolysin prostaglandin $F_{2\alpha}$ (PGF_{2 α}) about 17 d later so that estrus can be synchronized with normal fertility (Brown et al., 1988; Jaeger et al., 1992). Synchronized pregnancy rates (6-d) to this procedure have been reported to be about 49 to 57% and are similar to pregnancy rates in females that had been bred at non-synchronized estrus. More recently, females synchronized with the MGA/PGF_{2 α} procedure have been inseminated at a predetermined time but pregnancy rates range from 29-61% among locations (King et al., 1994; Larson et al., 1996). Because of the variable pregnancy rates, a combined 72-h insemination and insemination based on estrus procedure may be appropriate. The objectives

of this experiment were to determine 1) the optimal interval from the last day of MGA feeding to PGF_{2α} treatment, 2) the incidence of estrus during MGA treatment and after MGA and PGF_{2α} treatments, and 3) the efficacy of a combined 72-h insemination and insemination based on estrus breeding program.

MATERIALS AND METHODS

Beef females from the University of Illinois Beef Unit, Urbana, were included this study. Thirty-eight were heifers 12 to 15 months of age and 48 were postpartum cows suckling calves. Cows were 7 to 94 d postpartum when the experiment was initiated. All 86 of the females were group fed .5 mg of MGA per d for 14 d. MGA was fed in a total mixed diet balanced to meet or exceed all NRC (1985) requirements. Before any treatments were initiated, females were randomly assigned to one of three groups. PGF_{2α} (25 mg; 5 ml Lutalyse® sterile solution) was administered to females in these three groups 13, 15, and 17 d after the last d of MGA feeding. Beginning the first d of MGA feeding and continuing daily until 7 d after the 72-h AI, females were observed twice a d for estrous behavior. Females that stood to be mounted by other females were considered to be in estrus. During the 52 h immediately after PGF_{2α} treatment, females detected in estrus were artificially inseminated. At 72 h after PGF_{2α} treatment, all females not already inseminated were artificially inseminated. Females in estrus the 7 d following the 72-h AI were artificially inseminated using commercially frozen semen by the am/pm rule. Service sire selection was determined before assignment to groups. Females were examined per rectum for pregnancy 44-45 d after the 72-h AI.

Females determined to be pregnant at the per rectum examinations of the reproductive tracts were divided into four groups. Pregnant females not determined to be in estrus on d -2, -1, or +1 to +7 relative to PGF_{2α} treatment, were classified as pregnant to the 72-h AI. Pregnant females determined to be in estrus 1 to 3 d after the 72-h AI were classified as pregnant to the succeeding insemination. Pregnant females determined to be in estrus before the 72-h AI were classified as pregnant to an insemination preceding the 72-h AI. Pregnant females determined to be in estrus 1 to 2 d before and 1 to 3 d after the 72-h AI along with the females pregnant to the 72-h AI were classified as pregnant to the synchronized AI. Pregnant females in estrus on d 4 to 7 were classified as not pregnant to either the 72-h or synchronized inseminations.

Number of females in estrus and pregnancy data were analyzed by Chi-square analysis (Cochran and Cox, 1957).

RESULTS

Only two of the 86 females (2%) were detected in estrus during the 14 d MGA feeding period. Estrus was detected in those two females about 18 h after the first feeding. During the interval from the last d of MGA feeding to PGF_{2α} treatment, 16 of the 38 heifers (42%) and 6 of the 48 cows (13%) were detected in estrus an average of $5.4 \pm .4$ d after the last day of MGA feeding (Fig. 1). Although only a small percentage of the cows were detected in estrus after the last day of MGA feeding (but before PGF_{2α} treatment), mucous discharges were observed in a high percentage of the cows during the peak period of estrus. Because of the small number of females

and because no obvious differences were apparent for the expression of estrus and the establishment of pregnancy by heifers and cows after intervals of 13, 15, and 17 d between MGA and PGF_{2α}, they were summarized together. Only 5 of the 86 females (6%) were in estrus 1 or 2 d before the 72-h AI while 16 of the 86 females (19%) were in estrus 1 to 3 d after the 72-h AI (Fig. 1). Two of the 5 females (40%) in estrus before the 72-h AI became pregnant while 11 of the 16 females (69%) in estrus after the 72-h AI became pregnant. Of the other 65 females, although only 2 were detected in estrus 52 to 78 h after PGF_{2α} treatment, 25 of the 65 (39%) females with only 72-h AI became pregnant. The combined 6 d synchronized pregnancy rate was 44% (83/86).

DISCUSSION

MGA's efficacy in suppressing estrus in cattle has been well established (Zimbelman and Smith, 1966; Chenault et al., 1990) and with the exception of the two heifers that were observed in estrus about 18 h after the first feeding it was as effective in these studies. The two heifers that were in estrus may not have received a sufficient dosage of MGA at the first feeding because of the group feeding procedure. Chenault et al. (1990) reported a 1.5% incidence of estrus in heifers administered .5 mg of MGA daily for 7 d, however, that summary excluded d 1 when we observed females in estrus. Although MGA is effective in suppressing estrus, fertility of the estrus immediately after 14 to 18 d administration was reduced by 40 to 50% (Patterson et al., 1989 for review). The negative effect on fertility has been reported to be due to several factors (Hill et al., 1970; Lauderdale and Ericsson, 1970; Henricks et al., 1973). This effect occurred in females in which MGA was administered beyond the normal lifespan of corpora lutea (DeBois and Bierschwal, 1970; Beal et al., 1988). More recently it has been demonstrated that administration of MGA beyond the normal lifespan of corpora lutea allows dominant follicles to persist because MGA does not suppress pulsatile luteinizing hormone secretion (Kojima et al., 1995). Persistent dominant follicles create an estradiol abundant endocrine milieu and although oocytes were competent to be fertilized, their ability to reach the 16-cell stage was compromised (Ahmad et al., 1995). Anderson and Day (1994) demonstrated that progesterone administration during MGA feeding caused regression of persistent dominant follicles and fertility of the estrus immediately after MGA withdrawal was normal.

After the last d of MGA feeding the number of females that were detected in estrus in these studies was low although mucous discharges were observed in a majority of the females. For the females detected in estrus, the interval to estrus was variable and ranged from 2 to 8 d. The average interval to estrus was similar to unpublished data that included 2,352 females (J.R. Chenault, personal communication). In that study, the highest percentage (24.5%) of females that were in estrus on a given day was 4 d after the last d of MGA feeding but they reported a higher estrus response; 68% of the treated females were in estrus 2 to 5 d after the last d of MGA feeding.

Researchers have utilized the value of MGA and eliminated the negative effects on fertility by feeding MGA for about 14 d and then administering a luteolytic PGF_{2α} about 17 d later (Brown et al., 1988; Plugge et al., 1990; Jaeger et al., 1992; Patterson and Corah, 1992; Yelich et al., 1995; Patterson et al., 1995). Subsequent to PGF_{2α} treatment in most studies, females have been

bred at estrus via the am/pm rule. Six-d synchronized pregnancy rates to this procedure have been reported to be 49 to 57% in heifers and 15 to 68% in postpartum cows. Although this procedure is valuable, it still requires estrus detection and requires a long (approximately 37 d) period of time and results for cows are variable. More recently, however, females synchronized with the MGA/PGF_{2α} procedure have been 72-h inseminated although pregnancy rates range from 29 to 61% among locations (King et al., 1994; Larson et al., 1996).

Results in these experiments demonstrate that a combined 72-h breeding and breeding based on estrus detection program could be utilized with the MGA/PGF_{2α} estrus synchronization procedure. This may be particularly valuable in herds with a low percentage of the females displaying estrus after PGF_{2α} treatment. In this study, although only two females displayed estrus during the 26 hour period around estrus, 39% of the females not in estrus preceding or succeeding the 72 h timed AI established pregnancy to the 72-h AI.

Although the optimal interval from the last day of MGA feeding to PGF_{2α} treatment was not identified in this study, Kesler et al. (1996) established the optimal interval at 17 d for heifers and 15 d for cows. This was based on pregnancy rates to the 72-h AI which were similar to the pregnancy rates in this study. When the synchronized inseminations were evaluated (Kesler et al., 1996), pregnancy rates were similar among all three intervals (13, 15, and 17 d). Timed AI pregnancy rates in this study and the study by Kesler et al. (1996) are similar to pregnancy rates in females synchronized with Syncro-Mate B® and timed inseminated (Kesler and Favero, 1996).

IMPLICATIONS

Results from this study and others would suggest that the optimal interval from the last day of MGA feeding to PGF_{2α} treatment was 15 d for cows and 17 d for heifers. Acceptable pregnancy rates may be obtained by breeding cows at 72 h after PGF_{2α} treatment, however, pregnancy rates will be improved by breeding females in estrus the 2 d before and the 3 d after the 72-h timed AI.

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REFERENCES

- Ahmad, N., F.N. Schrick, R.L. Butcher, and E.K. Inskeep. 1995. Effect of persistent follicles on early embryonic losses in beef cows. *Biol. Reprod.* 52:1129.
- Anderson, L.H. and M.L. Day. 1994. Acute progesterone administration regresses persistent dominant follicles and improves fertility of cattle in which estrus was synchronized with melengestrol acetate. *J. Anim. Sci.* 72:2955.

- Beal, W.E., J.R. Chenault, M.L. Day, and L.R. Corah. 1988. Variation in conception rates following synchronization of estrus with melengestrol acetate and prostaglandin $F_{2\alpha}$. *J. Anim. Sci.* 66:599.
- Brown, L.N., K.G. Odde, M.E. King, D.E. LeFever, and C.J. Neubauer. 1988. Comparison of MGA-PGF $_{2\alpha}$ to Syncro-Mate B for estrous synchronization in beef heifers. *Theriogenology* 30:1.
- Chenault, J.R., J.F. McAllister, and C.W. Kasson. 1990. Synchronization of estrus with melengestrol acetate and prostaglandin $F_{2\alpha}$ in beef and dairy heifers. *J. Anim. Sci.* 68:296.
- Cochran, W.G. and G.M. Cox. 1957. *Experimental Design* (2nd Ed.). John Wiley & Sons, New York.
- DeBois, C.H.W. and C.J. Bierschwal, Jr. 1970. Estrous cycle synchronization in dairy cattle given a 14-day treatment of melengestrol acetate. *Am. J. Vet. Res.* 31:1545.
- Henricks, D.M., J.R. Hill, Jr., and J.F. Dickey. 1973. Plasma ovarian hormone levels and fertility in beef heifers treated with melengestrol acetate (MGA). *J. Anim. Sci.* 37:1169.
- Hill, J.R., Jr., D.R. Lamond, D.M. Henricks, J.F. Dickey, and G.D. Niswender. 1971. The effect of melengestrol acetate (MGA) on ovarian function and fertilization in beef heifers. *Biol. Reprod.* 4:16.
- Jaeger, J.R., J.C. Whittier, L.R. Corah, J.C. Meiske, K.C. Olson, and D.J. Patterson. 1992. Reproductive response of yearling beef heifers to a melengestrol acetate-prostaglandin $F_{2\alpha}$ estrus synchronization system. *J. Anim. Sci.* 70:2622.
- Kesler, D.J. and R.J. Favero. 1996. Estrus synchronization in beef females with norgestomet and estradiol valerate. Part 2: factors limiting and enhancing efficacy. *Agri-Practice* 17:12.
- Kesler, D.J., D.B. Faulkner, R.B. Shirley, T.S. Dyson, F.A. Ireland, R.S. Ott. 1996. Effect of interval from melengestrol acetate to prostaglandin $F_{2\alpha}$ on timed and synchronized pregnancy rates of beef heifers and cows. *J. Anim. Sci.* (In Press).
- King, M.E., M.J. Daniel, L.D. Teague, D.N. Schutz, and K.G. Odde. 1994. Comparison of timed insemination with insemination at estrus following synchronization of estrus with a MGA-prostaglandin system in beef heifers. *Theriogenology* 42:79.
- Kojima, F.N., J.R. Chenault, M.E. Wehrman, E.G. Bergfeld, A.S. Cupp, L.A. Werth, V. Mariscal, T. Sanchez, R.J. Kittok, and J.E. Kinder. 1995. Melengestrol acetate at greater doses than typically used for estrous synchrony in bovine females does not mimic

endogenous progesterone in regulation of secretion of luteinizing hormone and 17 β -estradiol. *Biol. Reprod.* 52:455.

Lauderdale, J.W. and R.J. Ericsson. 1970. Physiological conditions affecting the ability of cattle uteri to influence the fertilizing capacity of sperm. *Biol. Reprod.* 2:179.

Larson, R.L., L.R. Corah, and C.W. Peters. 1996. Synchronization of estrus in yearling heifers with the melengestrol acetate/prostaglandin F_{2 α} system: efficiency of timed insemination 72 hours after prostaglandin treatment. *Theriogenology* 45:851.

NRC. 1984. Nutrient Requirements of Beef Cattle. National Academy Press, Washington, DC.

Patterson, D.J., G.H. Kiracofe, J.S. Stevenson, and L.R. Corah. 1989. Control of the bovine estrous cycle with melengestrol acetate (MGA): a review. *J. Anim. Sci.* 67:1895.

Patterson, D.J. and L.R. Corah. 1992. Evaluation of a melengestrol acetate and prostaglandin F_{2 α} system for the synchronization of estrus in beef heifers. *Theriogenology* 38:441.

Patterson, D.J., J.B. Hall, N.W. Bradley, K.K. Schillo, B.L. Woods, and J.M. Kearnan. 1995. Improved synchrony, conception rate, and fecundity in postpartum suckled beef cows fed melengestrol acetate prior to prostaglandin F_{2 α} . *J. Anim. Sci.* 73:954.

Plugge, B.L., G.H. Deutscher, and M.K. Nielsen. 1990. Melengestrol acetate (MGA) and prostaglandin F_{2 α} program compared to Syncro-Mate B (SMB) for estrous synchronization utilizing AI or natural service. *Prof. Anim. Sci.* 6:29.

Yelich, J.V., H.S. Mauck, M.D. Holland, and K.G. Odde. 1995. Synchronization of estrus in suckled postpartum beef cows with melengestrol acetate and PGF_{2 α} . *Theriogenology* 43:389.

Zimbelman, R.G. and L.W. Smith. 1966. Control of ovulation in cattle with melengestrol acetate. I. Effect of dosage and route of administration. *J. Reprod. Fertil.* 11:185.

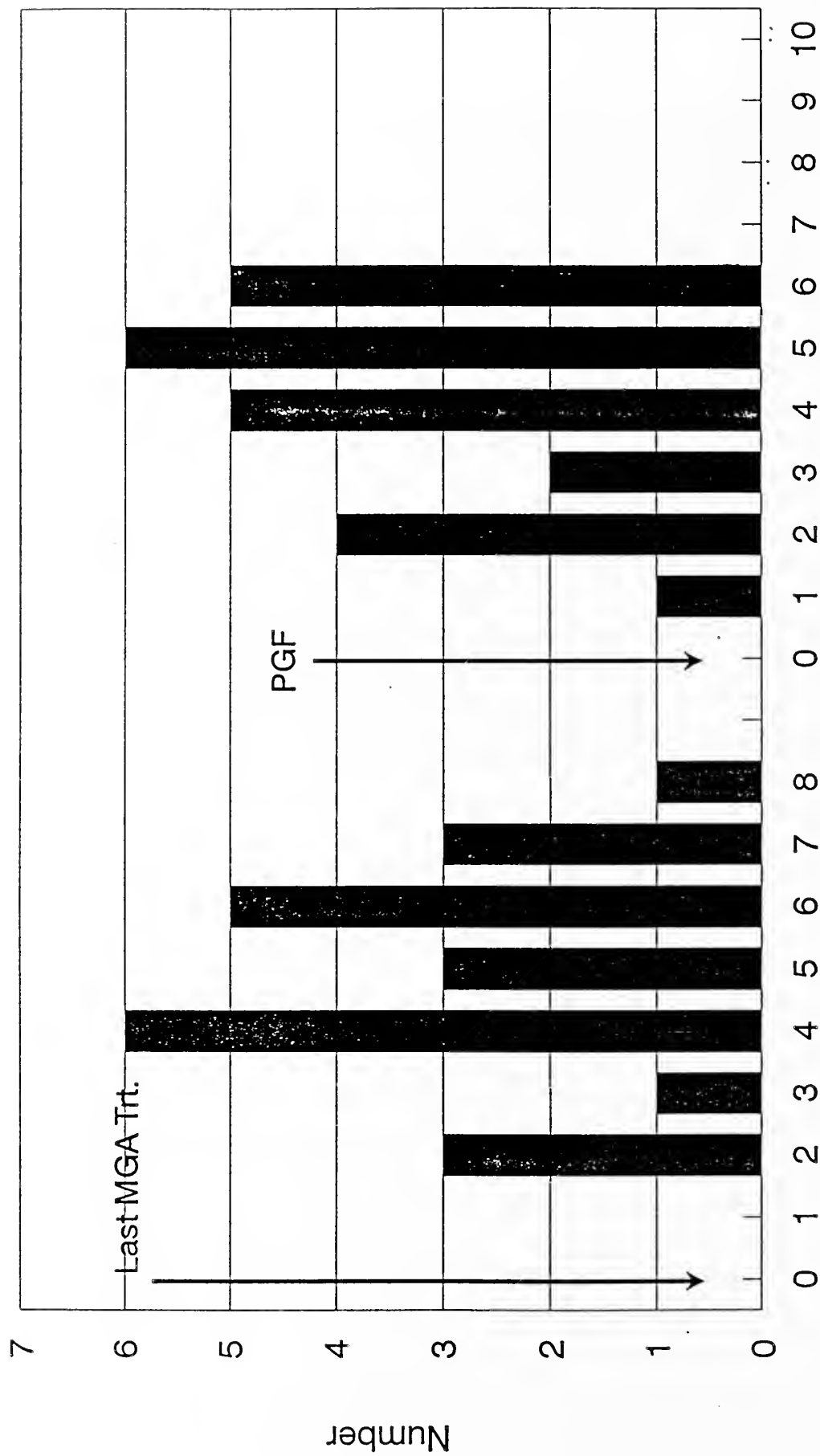


Fig. 1. Frequency of estrus after the last d of MGA feeding and after the $\text{PGF}_{2\alpha}$ treatment.

ESTRUS SYNCHRONIZATION IN BEEF FEMALES WITH SYNCRO-MATE B®: FACTORS LIMITING AND ENHANCING EFFICACY

D. J. Kesler and R. J. Favero

SUMMARY

Syncro-Mate B® is an effective procedure to synchronize estrus in beef cattle. The procedure utilizes an injection that contains norgestomet, a synthetic progestin, and estradiol valerate and a norgestomet implant that is left *in situ* for nine days. Removal of the implant allows for expression of fertile estrus approximately 30 to 56 hours later. Females may be timed bred approximately 48 to 54 hours after implant removal with approximately 40% of the treated females calving as a result of the timed insemination. Pregnancy rates have been somewhat variable because of non-synchronization (14% in this study), luteal dysfunction (9% in this study), stress, and other factors described herein.

INTRODUCTION

Syncro-Mate B® (SMB) is an efficacious FDA approved procedure to synchronize estrus in beef heifers, beef cattle, and dairy heifers (Darling, 1993). SMB is not only efficacious in cyclic cattle but also in pre-puberal heifers and anestrous cows (Hixon et al., 1981). Pregnancy rates for females bred subsequent to a SMB synchronization have been comparable to pregnancy rates for females bred at natural estrus but variability has been observed (Troxel and Kesler, 1982; Odde, 1990).

The objective of this study was to determine the incidence of luteal dysfunction and non-synchronization in SMB treated beef females: two factors that may contribute to the variability in pregnancy rates. An additional objective of this publication was to report various factors that limit and various factors that enhance pregnancy rates in SMB synchronized beef females.

MATERIALS AND METHODS

Six groups (herds) were administered SMB and artificially inseminated approximately 48 hours after implant removal. The six groups included 20 heifers (group 1), 15 heifers (group 2), 6 postpartum cows (group 3), 32 postpartum cows (group 4), 15 postpartum cows (group 5), and 22 heifers (group 6). The beef heifers were 12 to 15 months of age and the postpartum cows were mature beef cows 42 to 98 days postpartum suckling calves. The SMB treatment (Rhone Merieux, Inc., Overland Park, KS) consisted of an intramuscular injection of 3 mg norgestomet and 5 mg of estradiol valerate and the implantation of an implant containing 6 mg of norgestomet at the same time. The implant which was subcutaneously implanted on the convex surface of the ear was left *in situ* for 9 days. During the two weeks following artificial insemination (AI) cows were monitored for estrus behavior. In addition, cows were bled 6 or 7 days and 12 to 14 days after the timed AI. Two weeks after the timed AI bulls were included with cows. Pregnancy rates were determined at the following calving season.

All blood samples were centrifuged at 2,000 x g within 3 hours of collection and the serum was stored at - 20° C until assayed (Wiseman et al., 1983). All blood samples were assayed for progesterone concentrations by enzyme immunoassay (Kesler et al., 1990).

Females were determined not to be synchronized to the SMB treatment if estrus was detected 1 to 7 days after the timed AI and/or if progesterone concentrations in the sera were less than 1.0 ng/ml on days 6 or 7 post-AI (Kesler et al., 1981). Females were determined to have luteal dysfunction, short luteal phases, if progesterone concentrations were greater than 1.5 ng/ml on days 6 or 7 but less than 1.0 ng/ml on days 12 to 14 post-AI (Kesler et al., 1981).

The heifers of group 6 were analyzed separately because it was revealed that approximately 40 hours after norgestomet implant removal twelve of the heifers were relocated via a truck and trailer for approximately 6 hours and this handling had an effect on pregnancy rates.

Data were analyzed by analysis of variance (Hicks, 1964).

RESULTS

Of the 88 beef females included in this experiment (groups 1 to 5), 12 (14%) were not synchronized for a timed breeding 48 hours after norgestomet implant removal. Furthermore, 8 (9%) of the females had luteal dysfunction. Therefore, only 68 (77%) of the females were capable of establishing pregnancy to the timed breeding. Overall pregnancy rates were 46%, however, when non-synchronized females and females with luteal dysfunction were removed from the summary, pregnancy rates were improved to 60% (table 1).

In group 6, pregnancy rates for the control and relocated heifers were 6/10 (60%) and 2/12 (17%), respectively. The short term relocation, even in the absence of outward behavior signs of stress, reduced ($P < .05$) pregnancy rates.

DISCUSSION

Pregnancy rates in this experiment were variable and similar to data in the literature. For comparison purposes, pregnancy rates of studies using SMB are summarized in table 2. This is not a comprehensive summary and it only includes data from studies published in 1988 and onwards (Brink and Kiracofe, 1988; Brown et al., 1988; McVey and Williams, 1989; Favero et al., 1993; Troxel et al., 1993; Kesler et al., 1995; Favero et al., 1995; Steckler et al., 1995). This was not an attempt to include data from all publications and valuable data from older publications (Spitzer et al., 1978a; Spitzer et al., 1978b; Miksch et al., 1978; Kiser et al., 1980; Smith et al., 1979; Hixon et al., 1981 and others) were not included. Overall, pregnancy rates were 40% which is similar to our results of 46% from this experiment. Pregnancy rates in table 2 were similar for cows ($310/794 = 39\%$) and heifers ($176/418 = 42\%$) and were similar for our studies ($277/696 = 40\%$) and studies conducted by others ($209/516 = 41\%$). It should be noted, however, that these pregnancy rates were calculated by dividing the number pregnant (determined by calving in most cases) by the number treated for synchronization. If pregnancy rates had been calculated, as is done by many other researchers, by dividing the number pregnant (determined

at 42 day post-insemination) by the number observed in estrus, the pregnancy rates would have been considerably higher. Several factors, both from data herein and from data in the literature, that limit or enhance pregnancy rates in response to Syncro-Mate B estrus synchronization have been identified as follows.

1. **Non-Synchronization.** The overall non-synchronization rate to SMB has been reported to be 14% (data herein) and 16% (McVey and Williams, 1989). Pratt et al. (1991), Fanning et al. (1992), and Burns et al. (1993) reported that a major cause of non-synchronization was in females treated during metestrus (days 1 to 4 of the estrous cycle). Fanning et al. (1992) and Pratt et al. (1991) report that 42 to 48% of females treated during metestrus were not synchronized by SMB. In our studies (Kesler and Favero, 1995; Kesler et al., 1984) we have not observed a disproportional lack of response in metestrus females. However, the overall non-synchronization response of 14 to 16% is high.

2. **Luteal Dysfunction.** Results in this study demonstrate that 9% of the SMB treated females had luteal dysfunction or short luteal phases. Although these females may become pregnant, pregnancies are lost due to premature regression of the corpus luteum. Previous research has demonstrated that one procedure to reduce the incidence of short luteal phases is to administer norgestomet (Troxel and Kesler, 1984; Troxel et al., 1993). In those studies although the incidence of short luteal phases was significantly reduced, short luteal phases were not eliminated.

Favero et al. (1995) described a method (which is discussed in more detail later under factor number 10) to employ norgestomet for the reduction of luteal dysfunction under practical conditions. In early postpartum cows (< 42 days postpartum at the first timed AI), Favero et al. (1995) administered SMB followed by norgestomet treatment (via a silicone implant [Kesler et al., 1995]) 12 to 21 days after the SMB synchronized AI. Although the pregnancy rate to the SMB timed AI was low (27%; presumably due partially to luteal dysfunction), cows not conceiving to the SMB timed AI were synchronized after removal of the norgestomet/silicone implant and pregnancy rates to the second timed AI were equivalent to later postpartum cows (53%). The cows that conceived to the two timed AI's were an average of 29 and 42 days postpartum (at the first and second AI, respectively). Although this procedure requires more animal handling, if animal handling is feasible the benefits are enormous for improving pregnancy rates of early postpartum cows. In the study conducted by Favero et al. (1995) the calving interval for 57% of the cows (those that conceived to the first two AI's) was reduced by an average of 46 days.

3. **Time of AI in Relationship to Implant Removal.** We have previously demonstrated that heifers in later stages of the estrous cycle when treated with SMB, exhibited estrus earlier after implant removal than when heifers were treated earlier in the estrous cycle (Kesler and Favero, 1995). Based on the am/pm rule of AI, the heifers treated later in the estrous cycle would have been bred at a more appropriate time relative to the SMB timed breeding scheme than the heifers that were administered SMB earlier in the estrous cycle. Currently, it is recommended that if timed breeding is used, females should be bred at 48 to 54 hours after implant removal (Darling, 1993). Therefore, the timed breeding scheme may need re-evaluation, females may be bred based on thorough estrus detection, or heifers may be bred by timed breeding and then re-inseminated if a delayed estrus is detected. The later method produces the highest pregnancy rates.

4. Stress. Herein we have reported the negative effects of short-term relocation during the interval from implant removal and AI. In another study (Hixon et al., 1981), females were bled five times 24 to 36 hours after implant removal. In that study, pregnancy rates in the females that were bled was 21% (8/38) vs 40% (19/48) for females that were not bled. Bleeding was done via jugular venipuncture and statistically ($P < .05$) reduced pregnancy rates. Therefore, stress upon the treated females of any kind (with the exception of calf removal as described later) during the interval from implant removal to AI should be avoided.

5. Non-cyclicity. Data from table 2 clearly demonstrate the effect of synchronizing pre-pubertal and postpartum anestrous females. Combined, pregnancy rates in previously non-cyclic females was 24% (44/185) whereas pregnancy rates in cyclic females was 40%. Although pregnancy rates were far lower in previously non-cyclic females, 24% is a respectable pregnancy rate for previously non-cyclic females.

6. Estradiol Administration. Increasing the dosage of estradiol valerate (beyond 5 mg) has not improved SMB synchronization. In fact, first service pregnancy rates were reduced when higher dosages of estradiol valerate were used (Spitzer et al., 1978a; Pratt et al., 1991). It is possible that increased dosages of estradiol valerate result in elevated estradiol concentrations after implant removal, altering the optimal endocrine environment for gamete/embryo survival. Further, administration of any products containing estrogens during early pregnancy may cause corpus luteum regression and abortion (Favero et al., 1993; Aldrich et al., 1995).

Bo et al. (1993 and 1994), however, have demonstrated that estradiol valerate and estradiol-17 β , when administered along with a norgestomet implant, suppressed the growing phase of the dominant follicle and hastened the emergence of the second wave of follicular development. Therefore, appropriately timed estradiol to norgestomet implanted cows may allow cows to be synchronized at norgestomet implant removal without persistent follicles. Since persistent follicles have been demonstrated to suppress fertility/embryo development (Anderson and Day, 1994; Ahmad et al., 1995) a reduction in the incidence of persistent follicles may increase synchronized pregnancy rates (Anderson and Day, 1994). Therefore, further investigation is worthwhile in order to determine if this can be implemented into the SMB synchronization scheme. In the studies by Bo et al. (1993 and 1994), estradiol-17 β was more effective than estradiol valerate and estradiol was administered one or more days after implantation of the norgestomet implant, rather than at implantation, which requires more animal handling.

7. Dosage/Delivery of Norgestomet. Several studies have been conducted on altering the dosage of norgestomet during the nine day period. Increasing the dosage of norgestomet in the injection increased SMB synchronization and synchronized pregnancy rates of treated females (Fanning et al., 1992). In another study, although the amount of norgestomet in the injection and the total amount released from the implant were unaltered, the delivery profile was modified (Kesler et al., 1995). The amount of norgestomet released from the implant was reduced on day one and increased on all subsequent days (Kesler et al., 1995). Pregnancy rates in beef females treated with this implant (with the altered delivery profile) were 53% as compared to 44% observed in females administered the conventional SMB implant (Kesler et al., 1995).

This increase in norgestomet during the later stages of the nine day period may have caused more negative feedback on luteinizing hormone (LH) secretion (Sanchez et al., 1995) eliminating persistent follicles and therefore a higher rate of synchronization (Kesler and Favero, 1995) and/or higher fertility (Anderson and Day, 1994). Earlier research (Burns et al., 1993) and more recent research (Sanchez et al., 1995) have demonstrated that one commercial SMB norgestomet implant did not suppress the pulsatile secretion of LH. Furthermore, it has been demonstrated that slight increases in LH pulse frequency promoted prolonged ovarian follicular growth and dominance associated with increased concentrations of estradiol-17 β (Stock and Fortune, 1993).

8. Calf Removal. Both older and more recent studies demonstrate the beneficial effects of short-term calf removal (from implant removal to after AI) on pregnancy rates. Kiser et al. (1980) reported pregnancy rates of 39% and 51% for SMB synchronized beef cows without and with short-term calf removal, respectively. More recently, McVey and Williams (1989) reported pregnancy rates of 28% and 51% for SMB synchronized beef cows without and with short-term calf removal, respectively. However, improved pregnancy rates have not been noted in all studies (Smith et al., 1979).

9. Gonadotropin Releasing Hormone (GnRH) Treatment. We have conducted several studies in which GnRH was administered approximately 30 hours after norgestomet implant removal (Troxel et al., 1993; Valle et al., 1986a; Valle et al., 1986b). In all studies the administration of GnRH 30 hours after implant removal (approximately 18 hours before insemination) increased pregnancy rates. In the study by Troxel et al. (1993), GnRH administration increased pregnancy rates in both cyclic and previously non-cyclic postpartum beef cows from 18% to 46% (cyclic and previously non-cyclic cows combined). Although the dosage of GnRH used in these studies was 250 μ g, which makes the procedure financially impractical, a lower dosage (100 μ g) may be as effective.

Researchers have attempted to avoid the additional animal handling required for GnRH treatment by administering the GnRH at the time of norgestomet implant removal in a sustained delivery carrier (Favero et al., 1995; McVey and Williams, 1989). In both cases, the sustained release carriers used for GnRH, when administered at norgestomet implant removal, decreased pregnancy rates. The decrease in pregnancy rates may have been caused by a burst release at administration, however, when the burst release was eliminated although pregnancy rates were no longer decreased they were not improved (Favero et al., 1995).

10. Re-synchronization with Norgestomet. Administration of norgestomet implants during the luteal phase of inseminated females has been done in attempt to synchronize the second estrous cycle of nonpregnant females. This has been successfully accomplished with silicone norgestomet implants (Favero et al., 1993; Favero et al., 1995) but not with the SMB norgestomet implant (Washburn and McCraw, 1990). Not only were the second estrus synchronized in beef heifers but the pregnancy rates to the first insemination were enhanced (Favero et al., 1993). Used in early postpartum beef cows norgestomet implantation increased early postpartum pregnancy rates (Favero et al., 1995).

A summary of over 1200 females bred approximately 48 to 54 hours after implant removal demonstrate that approximately 40% of the treated females calve as a result of the timed insemination. However, several factors have been identified that compromise efficacy. Further, experimental methods of enhancing SMB synchronized pregnancy rates exist although no pharmacological products or procedures have been approved by the FDA.

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REFERENCES

- Aldrich SL, Berger LL, Kesler DJ, Faulkner DB, Castree J: Synovex® H as a prenatal androgenizing agent in beef cattle: effects on the implanted pregnant heifer. *Can. J. Anim. Sci.* (Submitted), 1995.
- Ahmad N, Schrick FN, Butcher RL, Inskeep EK: Effect of persistent follicles on early embryonic losses in beef cows. *Biol. Reprod.* 52:1129, 1995.
- Anderson LH, Day ML: Acute progesterone administration regresses persistent dominant follicles and improves fertility of cattle in which estrus was synchronized with melengestrol acetate. *J. Anim. Sci.* 72:2955, 1994.
- Bo GA, Adams GP, Nasser LF, Pierson RA, Mapletoft RJ: Effect of estradiol valerate on ovarian follicles, emergence of follicular waves and circulating gonadotropins in heifers. *Theriogenology* 40:225, 1993.
- Bo GA, Adams GP, Pierson RA, Tribulo HE, Caccia M, Mapletoft RJ: Follicular wave dynamics after estradiol-17 β treatment of heifers with or without a progestogen implant. *Theriogenology* 41:1555, 1994.
- Brink JT, Kiracofe GH: Effect of estrous cycle stage at Syncro-Mate B treatment on conception and time to estrus in cattle. *Theriogenology* 29:513, 1988.
- Brown LN, Odde KG, King ME, LeFever DG, Neubauer CJ: Comparison of melengestrol acetate-prostaglandin F_{2 α} to Syncro-Mate B for estrus synchronization in beef heifers. *Theriogenology* 30:1, 1988.
- Burns PD, Spitzer JC, Bridges WC, Henricks DM, Plyler BB: Effects of metestrous administration of a norgestomet implant and injection of norgestomet and estradiol valerate on luteinizing hormone release and development and function of corpora lutea in suckled beef cows. *J. Anim. Sci.* 71:983, 1993.

- Darling L: Veterinary Pharmaceuticals and Biologicals. Veterinary Medicine Publishing Co., Lenexa, Kansas, 1993, p. 892.
- Fanning MD, Spitzer JC, Burns GL, Plyler BB: Luteal function and reproductive response in suckled beef cows after metestrus administration of a norgestomet implant and injection of estradiol valerate with various dosages of injectable norgestomet. *J. Anim. Sci.* 70:1352, 1992.
- Favero RJ, Cruz LC, Kesler DJ: The effect of constant delivery of gonadotropin releasing hormone on fertility of cattle. *Drug Development and Industrial Pharmacy*, In Press, 1995.
- Favero RJ, Faulkner DB, Kesler DJ: Norgestomet implants synchronize estrus and enhance fertility in beef heifers subsequent to a Syncro-Mate B timed artificial insemination. *J. Anim. Sci.* 71:2594, 1993.
- Favero RJ, Faulkner DB, Nash TG, Kesler DJ: Effect of norgestomet treatment post-insemination on the calving rate of postpartum suckled beef cows. *J. Anim. Sci.* In press, 1995.
- Hicks CR: Fundamental Concepts in the Design of Experiments, Holt, Rinehart and Winston, New York, NY, 1964.
- Hixon DL, Kesler DJ, Troxel TR, Vincent DL, Wiseman BS: Reproductive hormone secretions and first service conception rate subsequent to ovulation control with Syncro-Mate B. *Theriogenology* 16:219, 1981.
- Kesler DJ, Favero RJ: Estrus synchronization in beef females with Syncro-Mate B®. 1. Mechanism of action. *Agri-Practice*, In Press, 1995.
- Kesler DJ, Favero RJ, Ruoff WL, Troxel TR: The effect of the stage of the estrous cycle on corpus luteum function of heifers treated with Syncro-Mate B. *Theriogenology* 21:243, 1984.
- Kesler DJ, Favero RJ, Troxel TR: A comparison of hydron and silicone implants in the bovine norgestomet and estradiol valerate estrus synchronization procedure. *Drug Development and Industrial Pharmacy* 21:475, 1995.
- Kesler DJ, Khazali H, Favero RJ: Quantification of steroids via a polymer linked second antibody enzyme immunoassay system: methods of linking anti-rabbit IgG to polystyrene. In: *Progress in Biomedical Polymers*. Ed., C.G. Gebelein and R.L. Dunn, Plenum Publishing Co., New York, NY, 1990, pp. 157.

- Kesler DJ, Weston PG, Pimentel CA, Troxel TR, Vincent DL, Hixon JE: Diminution of the *in vitro* response to luteinizing hormone by corpora lutea induced by gonadotropin releasing hormone treatment of postpartum suckled beef cows. *J. Anim. Sci.* 53:749, 1981.
- Kiser TE, Dunlap SE, Benyshek LL, Mares SE: The effect of calf removal on estrous response and pregnancy rate of beef cows after Syncro-Mate B treatment. *Theriogenology* 13:381, 1980.
- McVey WR, Williams GL: Effect of temporary calf removal and osmotic pump delivery of gonadotropin releasing hormone on synchronized estrus, conception to a timed artificial insemination and gonadotropin secretion in norgestomet-estradiol valerate-treated cattle. *Theriogenology* 32:969, 1989.
- Miksch ED, LeFever DG, Mukembo G, Spitzer JC, Wiltbank JN: Synchronization of estrus in beef cattle. II. Effect of an injection of norgestomet and an estrogen in conjunction with a norgestomet implant in heifers and cows. *Theriogenology* 10:201, 1978.
- Odde KB: A review of synchronization of estrus in postpartum cattle. *J. Anim. Sci.* 68:817, 1990.
- Pratt SL, Spitzer JC, Burns GL, Plyler BB: Luteal function, estrous response and pregnancy rate after treatment with norgestomet and various dosages of estradiol valerate in suckled cows. *J. Anim. Sci.* 69:2721, 1991.
- Sanchez T, Wehrman ME, Kojima FN, Cupp AS, Bergfeld EG, Peters KE, Mariscal V, Kittok RJ, Kinder JE: Dosage of the synthetic progestin, norgestomet, influences luteinizing hormone pulse frequency and endogenous secretion of 17 β -estradiol in heifers. *Biol. Reprod.* 52:464, 1995.
- Smith MF, Burrell WC, Shipp LD, Sprott LR, Songster WN, Wiltbank JN: Hormone treatments and use of calf removal in postpartum beef cows. *J. Anim. Sci.* 48:1285, 1979.
- Spitzer JC, Burrell WC, LeFever DG, Whitman RW, Wiltbank, JN: Synchronization of estrus in beef cattle. I. Utilization of a norgestomet implant and injection of estradiol valerate. *Theriogenology* 10:181, 1978a.
- Spitzer JC, Jones DL, Miksch ED, Wiltbank JN: Synchronization of estrus in beef cattle. III. Field trials in heifers using a norgestomet implant and injections of norgestomet and estradiol valerate. *Theriogenology* 10:223, 1978b.
- Steckler TL, Machado R, Dyson TS, Faulkner DB, Kesler DJ: The effect of prostaglandin F_{2 α} administration before Syncro-Mate B[®] on timed pregnancy rates. *J. Anim. Sci.* 73(Suppl. 1):90, 1995.

- Stock AE, Fortune JE: Ovarian follicular dominance in cattle: relationship between prolonged growth of the ovulatory follicle and endocrine parameters. *Endocrinology* 132:1108, 1993.
- Troxel TR, Kesler DJ: The bovine estrous cycle: dynamics and control. Cooperative Extension Service Circular 1205, University of Illinois, Urbana, 1982, 15 pp.
- Troxel TR, Kesler DJ: The effect of progestin and GnRH treatments on ovarian function and reproductive hormone secretions of anestrous postpartum suckled beef cows. *Theriogenology* 21:699, 1984.
- Troxel TR, Cruz LC, Ott RS, Kesler DJ: Norgestomet and gonadotropin releasing hormone enhance corpus luteum function and fertility of postpartum suckled beef cows. *J. Anim. Sci.* 71:2579, 1993.
- Valle ER, Cruz LC, Cmarik GF, Ott RS, Peterson LA, Kesler DJ: The effect of GnRH and its method of administration on ovulation response, corpus luteum function and fertility of beef heifers synchronized with norgestomet and PGF_{2α}. *J. Anim. Sci.* 63 (Suppl. 1):132, 1986a.
- Valle ER, Cruz LC, Cmarik GF, Ott RS, Peterson LA, Kesler DJ: The effect of short term calf removal, GnRH and its method of administration on ovulation response, corpus luteum function and fertility of postpartum suckled beef cows synchronized with norgestomet and PGF_{2α}. *J. Anim. Sci.* 63 (Suppl. 1):132, 1986b.
- Washburn SP, McCraw RL: Use of norgestomet implants after insemination to synchronize repeat estruses in beef cows. *J. Anim. Sci.* 68 (Suppl. 1):13, 1990.
- Wiseman BS, Vincent DL, Thomford PJ, Scheffrahn NS, Sargent GF, Kesler DJ: Changes in porcine, ovine, bovine and equine blood progesterone concentrations between collection and centrifugation. *Anim. Reprod. Sci.* 5:157, 1983.

Table 1. Pregnancy rates of beef females administered Syncro-Mate B®.

Group	n	Type of Female	Pregnancy Rates (%) ^a	
			All	Synchronized/Normal ^b
1	20	Heifers	70	82
2	15	Heifers	60	73
3	6	Postpartum cows	17	33
4	32	Postpartum cows	38	52
5	15	Postpartum cows	33	42
All	88		46	60

^aPregnancy rates were based on the total number of females treated for synchronization (number pregnant ÷ number treated for synchronization).

^bOnly females determined to be synchronized and not have luteal dysfunction.

Table 2. Pregnancy rates of females synchronized with Syncro-Mate B® and timed bred^a after implant removal.

Reference	Year	Females	Cyclic Status	n	Pregnancy Rate ^b
Brink and Kiracofe	1988	heifers	cyclic	85	42%
Brink and Kiracofe	1988	cows	cyclic	94	48%
Brink and Kiracofe	1988	cows	non-cyclic	37	30%
Brown et al.	1988	heifers	cyclic	92	45%
Brown et al.	1988	heifers	non-cyclic	61	26%
McVey and Williams	1989	heifers	n/a ^c	34	47%
McVey and Williams	1989	cows	n/a	58	28%
McVey and Williams	1989	cows + cr ^d	n/a	55	51%
Favero et al.	1993	heifers	n/a	42	21%
Favero et al.	1993	heifers	n/a	19	53%
Troxel et al.	1993	cows	cyclic	51	22%
Troxel et al.	1993	cows	non-cyclic	49	14%
Kesler et al.	1995	cows	n/a	91	48%
Kesler et al.	1995	heifers	n/a	40	35%
Favero et al.	1995	cows	n/a	85	49%
Favero et al.	1995	cows	n/a	88	50%
Steckler et al.	1995	cows	cyclic	95	36%
Steckler et al.	1995	cows	non-cyclic	38	26%
Data herein	1995	cows	n/a	53	34%
Data herein	1995	heifers	n/a	35	66%
Data herein	1995	heifers	n/a	10	60%
Combined				1202	40%

^aFemales were timed bred approximately 48 to 54 hours after norgestomet implant removal.

^bPregnancy rates were based on the total number of females treated for synchronization (number pregnant ÷ number treated for synchronization).

^cNot available.

^dCalf removal.

ESTRUS SYNCHRONIZATION IN BEEF FEMALES WITH SYNCRO-MATE B®: MECHANISM OF ACTION

D. J. Kesler and R. J. Favero

SUMMARY

Syncro-Mate B® is an effective procedure to synchronize estrus and ovulation in beef cattle. The procedure utilizes an injection that contains norgestomet, a synthetic progestin, and estradiol valerate and a norgestomet implant that is left *in situ* for nine days. The combined procedure reduces progesterone concentrations by preventing development or causing regression of corpora lutea during the nine day treatment period. The norgestomet released from the implant suppresses estrus and removal of the implant allows for expression of fertile estrus approximately 31 to 56 hours later.

INTRODUCTION

Syncro-Mate B® (SMB) is an efficacious FDA approved procedure to synchronize estrus in beef heifers, beef cows, and dairy heifers (Darling, 1993). SMB is not only efficacious in cyclic cattle but also in pre-puberal heifers and anestrus cows (Hixon et al., 1981). Although, pregnancy rates for females bred subsequent to a SMB synchronization have been comparable to pregnancy rates for females bred at natural estrus, variability has been observed (Troxel and Kesler, 1982; Odde, 1990).

SMB utilizes norgestomet, a potent synthetic progestin, and a long acting estradiol-17 β ester, estradiol valerate, in a nine day treatment period (Chien, 1978). Females in the later stages of the estrous cycle rely on the norgestomet from the implant to suppress estrus after corpus luteum regression. Females in the earlier stages of the estrous cycle have premature corpus luteum regression allowing all females to exhibit estrus 1 to 3 days after implant removal (Troxel and Kesler, 1982). Progesterone secretion by corpora lutea during the SMB treatment and the mechanism of action, however, have not been elucidated.

The objective of this study was to determine progesterone secretion of heifers during SMB treatment when administered on various days of the estrous cycle. An additional objective was to describe the mechanism of action by which SMB is capable of synchronizing estrus.

MATERIALS AND METHODS

Thirty-seven cross-bred beef heifers (12 to 15 months of age), selected from a larger group of heifers because they had been detected in estrus during the previous 19 days, were included in this study. Heifers were divided into stage of the estrous cycle based on the number of days since the previous estrus. SMB treatment was administered on days 2 to 4 (n=8), days 5 to 7 (n=4), days 8 to 10 (n=8), and days 11 to 13 (n=5) of the estrous cycle (referred to as days 3, 6, 9, and 12 of the estrous cycle, respectively). Twelve heifers were not treated with SMB and served as controls. The SMB treatment (Rhone Merieux, Inc., Overland Park, KS) consisted of an

intramuscular injection of 3 mg norgestomet and 5 mg of estradiol valerate and the implantation of an implant containing 6 mg of norgestomet at the same time. The implant which was subcutaneously implanted on the convex surface of the ear was left in situ for 9 days. All heifers were bled immediately prior to SMB treatment and 3, 6, and 9 days post-treatment. Twelve days after implant removal all heifers were ovariectomized and ovaries were grossly examined for the presence of corpora lutea.

All blood samples were centrifuged at 2,000 x g within 3 hours of collection and the serum was stored at - 20° C until assayed (Wiseman et al., 1983). All blood samples were assayed for progesterone concentrations by enzyme immunoassay (Kesler et al., 1990).

Data were analyzed by analysis of variance (Hicks, 1964).

RESULTS

All heifers were detected in estrus within 56 hours after SMB implant removal. The mean intervals from implant removal to the first observation of estrus, by stage of estrous cycle when heifers were treated, are reported in table 1. Overall, the interval ranged from 31 to 56 hours but no statistical differences ($P > .10$) were detected. In general, however, the interval from implant removal to estrus was shorter as the stage of the estrous cycle when treated increased. Heifers treated on days 2 to 7 of the estrous cycle exhibited estrus 44 to 56 hours after implant removal whereas heifers treated on days 8 to 13 of the estrous cycle exhibited estrus 31 to 46 hours after implant removal. Each heifer had a corpus luteum at the time of ovariectomy indicating that all the synchronized estrus were ovulatory.

SMB treatment had a significant ($P < .05$) effect on progesterone secretion at all stages of the estrous cycle (figure 1). When SMB was administered on days 2 to 4 of the estrous cycle, progesterone concentrations continued to increase up to day 6 and then fell to baseline concentrations within 3 days after treatment and remained at baseline until implants were removed. When SMB was administered on days 5 to 7 of the estrous cycle, progesterone concentrations continued to increase for the next 6 days and then fell to less than 1.0 ng/ml by the time of implant removal. Administration of SMB on days 8 to 13 of the estrous cycle caused progesterone concentrations to gradually fall to less than 1.0 ng/ml by the time of implant removal.

DISCUSSION

Chemically, norgestomet (17 α -acetoxy-11 β -methyl-19-norpreg-4-ene-20, dione) is a modified 19-norprogesterone. Norgestomet has been demonstrated to be a highly biologically active progestin. Gilbert et al. (1974) demonstrated that norgestomet is 15 times more biological active than progesterone when orally administered to rabbits. Gilbert et al. (1974) further demonstrated that norgestomet was 216 times more biologically active than progesterone when subcutaneously administered to estradiol-17 β treated mice. By injection Wishart (1972) determined and by implant delivery Machado and Kesler (1995) confirmed that 140 μ g of norgestomet and 45 mg of progesterone (Wishart, 1972) were required to suppress estrus in all treated heifers (which

means that norgestomet is 321 times more potent than progesterone in this model). Norgestomet is metabolized quickly (Moffatt et al., 1993) and is excreted in the urine and feces (Searle, 1982).

Norgestomet's principal mode of action for estrus synchronization is by suppressing estrus. Further, norgestomet has the progesterone biological activity to maintain pregnancy in ovariectomized heifers (Favero et al., 1990; Kesler and Favero, 1995) and to block estradiol induced pre-ovulatory luteinizing hormone (LH) surges (Bo et al., 1994). Favero et al. (1990) and Kesler et al. (1995) demonstrated that norgestomet maintained pregnancy from day 10 through parturition. Upon removal of the norgestomet implants, parturition (if the implants were removed at term) or abortion (if the implants were removed at mid-gestation or earlier) occurred within 52 hours. Therefore, norgestomet is as effective as progesterone (but at a substantially reduced dosage) for three of progesterone's main biological actions: 1) estrus suppression, 2) inhibition of the pre-ovulatory LH surge, and 3) pregnancy maintenance. Norgestomet's ability to regulate pulsatile LH secretion and follicular growth and maturation requires a higher dosage and will be discussed later.

Along with norgestomet, estradiol valerate is included with the injectable portion of the procedure. Estradiol valerate is an estradiol-17 β ester modified at the 17 position. The esterification increases in vivo half-life. Although very little blood data exist in the literature, the data available suggest that estradiol valerate is a very long acting compound. The administration of 5 mg to women elevated blood estradiol concentrations for 7 to 12 days (Sinkula, 1978). Data in cattle are equivocal (Troxel et al., 1980; Ashimine et al., 1991; Kojima et al., 1992; Bo et al., 1993). Troxel et al. (1980) and Bo et al. (1993) demonstrated that estradiol concentrations returned to baseline by the end of the nine day treatment program. Ashimine et al. (1991) and Kojima et al. (1992) reported elevated estradiol concentrations on day 9. The varying results may be caused by persistent follicle development (Rajamahendran and Taylor, 1991; Savio et al., 1993). Savio et al. (1993) and Ahmad et al. (1995) have demonstrated that persistent follicle secrete high concentrations of estradiol and the incidence (or duration) of persistent follicles depends on the stage of the estrous cycle when the norgestomet implant is inserted but they are associated with reduced fertility (Anderson and Day, 1994; Ahmad et al., 1995).

Interestingly, McGuire et al. (1990) have demonstrated that ovariectomized cows and heifers administered SMB exhibit estrus subsequent to removal of the norgestomet implant at a similar time after implant removal as for intact cows and heifers. The cause of this estrus in ovariectomized cows and heifers has not been established, however, it may result from residual estradiol from the estradiol valerate injection at SMB treatment nine days earlier. Although norgestomet does exhibit weak estrogenic activity when tested in an estrogen-dependent stimulation of human breast cell test, it does not interact with endometrial estrogen receptors (Moffatt et al., 1993). Based on human breast cell test results, in order to provoke estrogen stimulation, a dose of 100 mg of norgestomet given at one time would be required (Moffatt et al., 1993). Therefore the estrus subsequent to norgestomet removal in ovariectomized cows and heifers is unlikely due to the norgestomet. Alternatively, after norgestomet implant removal, cows and heifers are more sensitive to estradiol stimulation that may be synthesized by extraovarian sources in ovariectomized cows and heifers.

The mechanism(s) by which SMB regulates reproductive events so that all treated females are synchronized has not been fully elucidated. In regards to early treatment (treatment on day 2 to 4 of the estrous cycle), however, the results of this study support the results of Lemon (1975) and Kesler et al. (1984) in that administration of a combined treatment of norgestomet and estradiol valerate (SMB) suppressed corpus luteum development. Progesterone secretion when SMB is administered at this early stage of the estrous cycle is similar to progesterone secretion in females with luteal dysfunction (Kesler et al., 1981; Troxel and Kesler, 1984). We hypothesize that in these situations the combined treatment causes a delayed luteolytic effect. This is based on the following facts.

1. The corpus luteum does not lyse in response to prostaglandin $F_{2\alpha}$ $PGF_{2\alpha}$ until the fifth day after estrus (Lauderdale, 1972; Lauderdale, 1975).
2. Peak progesterone secretion occurs on the 5 th or 6 th day of the estrous cycle (Kesler et al., 1981; Troxel and Kesler, 1984; Kesler et al., 1984).
3. Estradiol therapy increases the sensitivity of the corpus luteum to luteolytic prostaglandins (Hixon et al., 1983).

It is possible that luteolytic prostaglandins become elevated subsequent to SMB treatment and the elevated concentrations of estradiol enhance $PGF_{2\alpha}$ lysis of the corpus luteum just as soon as the corpus luteum becomes responsive to prostaglandin $F_{2\alpha}$.

Alternatively, it is possible that the deficiency of LH, subsequent to SMB treatment, is involved when SMB is administered on days 2 to 4 of the estrous cycle. We have previously demonstrated that there is a delay in corpus luteum stimulated progesterone secretion to LH (until the seventh day of the estrous cycle [Kesler et al., 1981]). Therefore, the delayed regression observed may occur because when the corpus luteum becomes responsive to LH, but in the absence of LH, the corpus luteum regresses. However, since Burns et al. (1993) revealed no differences in LH secretion (both basal LH concentrations and LH pulses) between cows that had corpus luteum regression and corpus luteum maintenance, an alternative cause such as the involvement of a luteolysin is more likely.

The effect of SMB on corpora lutea on days 5 to 10 of the estrous cycle is less obvious. During these days of the estrous cycle although corpus luteum regression is premature, lysis does not occur as abruptly as would be anticipated for $PGF_{2\alpha}$ induced corpus luteum lysis. Progesterone secretion subsequent to SMB treatment on days 5 to 10 of the estrous cycle however would suggest that the combined treatments are causing an anti-luteotropic effect. It is well established that the combined treatment of progesterone and estradiol suppresses LH synthesis and secretion (Beck et al., 1976). In fact, inclusion of estradiol with progesterone appears to intensify the negative feedback on LH secretion compared to progesterone alone (Beck et al., 1976). It has been demonstrated that SMB treatment causes a decrease in both basal LH concentrations and in the number of LH pulses (Burnes et al., 1993). This feedback is continuous for several days since norgestomet is continually released from the implant and estradiol valerate has a long half-life and it is likely to be present for much of the nine day treatment period. Therefore, it is possible that in the presence of a deficiency of the luteotropin LH, corpus luteum regression occurs within nine days. If a luteolysin is involved, its effect is much more gradual than $PGF_{2\alpha}$.

A study to determine the effect of suppressing the pulsatile release of LH on corpus luteum function were conducted by Peters et al. (1994). In that study it was demonstrated that corpus luteum development and maintenance was suppressed, although not inhibited, by administering a gonadotropin releasing hormone (GnRH) antagonist on days 2 to 7 or 7 to 12 of the estrous cycle. Although the LH pulses were suppressed in GnRH antagonist treated heifers, basal levels of LH remained in circulation (Peters et al., 1994). The lifespan of the corpus luteum of GnRH antagonist treated heifers appeared to be similar to the lifespan of the corpus luteum in untreated heifers. No direct comparisons on LH secretion have been made between estradiol/progestin treated heifers and GnRH antagonist treated heifers. However, it may be that estradiol and progestin treatment not only suppresses the pulsatile LH secretion like GnRH antagonist, but suppresses the basal concentrations of LH more than GnRH antagonist therefore providing less luteotropic support for corpus luteum development and maintenance than GnRH antagonist (Burns et al., 1993).

When SMB was administered on days 11 to 13 of the estrous cycle progesterone concentrations decreased more rapidly than when SMB was administered on days 5 to 10 of the estrous cycle. However, the decrease in progesterone concentrations still was not as abrupt as when cows at a similar stage of the estrous cycle were administered $\text{PGF}_{2\alpha}$. Therefore, either the luteolytic response is more gradual than observed for pharmacological administration of $\text{PGF}_{2\alpha}$ or the mature corpus luteum is more responsive to the deficiency of the LH caused by the norgestomet and estradiol valerate induced negative feedback.

Regression of the corpus luteum appears to occur when SMB is administered on approximately day 12 of the estrous cycle regardless of presence or absence of the embryo. Favero et al. (1993) administered SMB to inseminated cows 12 days after breeding and reported pregnancy rates of 5 % and 53 % for SMB treated and untreated heifers. Administration of norgestomet alone, however, on days 12 through 21 of the estrous cycle had no effect on progesterone secretion by corpora lutea (Domatob et. al., 1994) and no negative effects on the establishment of pregnancy (Favero et. al., 1993; Favero et al., 1995). In order to assess the effect of norgestomet on early bovine corpus luteum formation and development, norgestomet was administered on days 1, 2, 3, and 4 after estrus (two cows per day). The implants were left in situ for 12 days. In all eight cows, corpora lutea development, progesterone secretion, and estrus cycle length were unaffected by norgestomet treatment (Kesler, 1995). Therefore, negative feedback of norgestomet alone during metestrus and diestrus did not disrupt corpora lutea development or function. It is more likely that the estradiol component of the SMB procedure caused corpus luteum regression and abortion since Aldrich et al. (1995) demonstrated an abortifacient effect of estradiol benzoate/testosterone propionate implants in heifers. Aldrich et al. (1995) also reported a decrease in progesterone concentrations subsequent to estradiol benzoate/testosterone propionate implantation.

In addition to regulating luteal function, it is necessary to have an ovulatory follicle with a viable oocyte available for ovulation after removal of the norgestomet implant. When the SMB norgestomet implant was implanted during proestrus, the dominant follicle present was maintained for the duration of the treatment and there was no growth of medium or small follicles (Rajamahendran and Taylor, 1991). Systemic estradiol concentrations were also elevated, and

there was insufficient progestin activity to maintain a strong negative feedback on LH pulse frequency in a manner comparable to that of the luteal phase of a normal estrous cycle (Savio et. al., 1993). Rajamahendran and Taylor (1991) suggested that this implied that the norgestomet treatment given during pro-estrus mimics the actions of low concentrations of progesterone. This time period is, in fact, a time of low norgestomet release by the SMB norgestomet implant (Kesler et. al., 1995) and, therefore, obtaining a low progestin effect would be expected. In fact, when implants were changed during the persistence of the dominant follicle, LH pulse frequency decreased, estradiol concentrations decreased, and follicular atresia occurred (Savio et. al., 1993). Therefore, when given in appropriate amounts, norgestomet was effective in provoking the progestin-like negative feedback on LH pulse frequency and on follicular atresia. However, during the end of the nine day implantation period it appears that the SMB norgestomet implant is not capable of provoking enough negative feedback to suppress LH release. Sanchez et al. (1995) reported that two SMB norgestomet implants were effective in suppressing the pulsatile LH release and establishing normal estradiol concentrations. Similarly, Butcher et. al. (1992) reported that daily injections of 100 mg/day was required to elevate systemic progesterone concentrations to levels of the luteal phase (5 to 7 ng/ml). Whereas, daily injections of only 45 mg/day were required to suppress estrus in all treated animals (Wishart, 1972). The dosage selected for the SMB norgestomet implant was based on the minimal quantity required to suppress estrus.

It may be that in addition to the frequent development of persistent dominant follicles during the SMB procedure (Kesler and Favero, 1995 for review), secondary follicles are capable of ovulating after norgestomet implant removal (Kesler and Favero, 1995). Kesler and Favero (1995) ovariectomized heifers after synchronization with SMB and reported a 20 % incidence of multiple ovulations. This is higher than the anticipated twinning rate for heifers of their genotype. Furthermore, when HCG was administered at estrus, the incidence of multiple ovulations was increased to 40 %.

In summary, the SMB procedure reduces progesterone concentrations and causes regression of corpora lutea within the nine day treatment period. Regression occurs as result of a luteolysin and/or because of anti-luteotropic effects. The norgestomet released from the implant suppresses estrus and removal of the implant allows expression of fertile estrus approximately 31 to 56 hours later.

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REFERENCES

- Aldrich SL, Berger LL, Kesler DJ, Faulkner DB, Castree J: Synovex® H as a prenatal androgenizing agent in beef cattle: effects on the implanted pregnant heifer. *Can. J. Anim. Sci.* (Submitted), 1995.

- Ahmad N, Schrick FN, Butcher RL, Inskeep EK: Effect of persistent follicles on early embryonic losses in beef cows. *Biol. Reprod.* 52:1129, 1995.
- Anderson LH, Day ML: Acute progesterone administration regresses persistent dominant follicles and improves fertility of cattle in which estrus was synchronized with melengestrol acetate. *J. Anim. Sci.* 72:2955, 1994.
- Ashimine D, Miller-Patrick K, Webster H, Weems C, Vincent D: Sources of increased estradiol (E) following Syncro-Mate B (SMB) in beef heifers. *J. Anim. Sci.* 69(Suppl. 1):400.
- Beck TW, Smith VG, Sequin BE, Convey EM: Bovine serum LH, GH and prolactin following chronic implantation of ovarian steroids and subsequent ovariectomy. *J. Anim. Sci.* 42:461, 1976.
- Bo GA, Adams GP, Nasser LF, Pierson RA, Mapletoft RJ: Effect of estradiol valerate on ovarian follicles, emergence of follicular waves and circulating gonadotropins in heifers. *Theriogenology* 40:225, 1993.
- Bo GA, Adams GP, Pierson RA, Tribulo HE, Caccia M, Mapletoft RJ: Follicular wave dynamics after estradiol-17 β treatment of heifers with or without a progestogen implant. *Theriogenology* 41:1555, 1994.
- Burns PD, Spitzer JC, Bridges WC, Henricks DM, Plyler BB: Effects of metestrous administration of a norgestomet implant and injection of norgestomet and estradiol valerate on luteinizing hormone release and development and function of corpora lutea in suckled beef cows. *J. Anim. Sci.* 71:983, 1993.
- Butcher RL, Reber JE, Lishman AW, Breuel KF, Schrick FN, Spitzer JC, Inskeep EK: Maintenance of pregnancy in postpartum beef cows that have short-lived corpora lutea. *J. Anim. Sci.* 70:3831, 1992.
- Chien YE: Methods to achieve sustained drug delivery. A physical approach: implants. In Robinson, J.R. (ed.). *Sustained and Controlled Release Drug Delivery Systems*. Marcel Dekker, Inc., New York, 1978, pp. 326.
- Darling L: *Veterinary Pharmaceuticals and Biologicals*. Veterinary Medicine Publishing Co., Lenexa, Kansas, 1993, p. 892.
- Domatob FN, Machado R, Ireland FA, Faulkner DB, Kesler DJ: Progesterone and electrical resistance effectively diagnose pregnancy in beef heifers after norgestomet re-synchronization. *J. Anim. Sci.* 72(Suppl. 1):173, 1995.
- Favero RJ, Faulkner DB, Kesler DJ: Norgestomet implants synchronize estrus and enhance fertility in beef heifers subsequent to a Syncro-Mate B timed artificial insemination. *J. Anim. Sci.* 71:2594, 1993.

- Favero RJ, Faulkner DB, Nash TG, Kesler DJ: Effect of norgestomet treatment post-insemination on the calving rate of postpartum suckled beef cows. J. Anim. Sci. In press, 1995.
- Favero RJ, Henderson EA, Kesler DJ: The ability of norgestomet impregnated polydimethylsiloxane implants to maintain pregnancy subsequent to ovariectomy. In: Progress in Biomedical Polymers. Ed., C.G. Gebelein and R.L. Dunn, Plenum Publishing Co., New York, NY, 1990, pp. 355.
- Gilbert HG, Phillipps GH, English AF, Stephenson L, Woollett EA, Newall CE, Child KJ: The progestational and anti-estrogenic activities of some novel 11 β -substituted steroids. Steroids 23: 585, 1974.
- Hicks CR: Fundamental Concepts in the Design of Experiments, Holt, Rinehart and Winston, New York, NY, 1964.
- Hixon DL, Kesler DJ, Troxel TR, Vincent DL, Wiseman BS: Reproductive hormone secretions and first service conception rate subsequent to ovulation control with Syncro-Mate B. Theriogenology 16:219, 1981.
- Hixon JE, Pimentel CA, Weston PG, Chafetz EP, Shanks RD, Hansel W: A luteolytic interaction between estradiol benzoate and prostaglandin F_{2 α} in cattle. J. Anim. Sci. 56:1190, 1983.
- Kesler DJ: Remotely-delivered contraception with needle-less norgestomet implants. In: Contraception in Wildlife Management. Ed. T.J Kreeger, U.S. Government Printing Office, Washington, D.C., In Press, 1995.
- Kesler DJ, Favero RJ: Estrus synchronization in beef females with Syncro-Mate B®. 2. Factors limiting and enhancing efficacy. Agri-Practice, In Press, 1995.
- Kesler DJ, Favero RJ: Norgestomet implants maintain pregnancy in ovariectomized heifers. J. Dairy Sci., Submitted, 1995.
- Kesler DJ, Khazali H, Favero RJ: Quantification of steroids via a polymer linked second antibody enzyme immunoassay system: methods of linking anti-rabbit IgG to polystyrene. In: Progress in Biomedical Polymers. Ed., C.G. Gebelein and R.L. Dunn, Plenum Publishing Co., New York, NY, 1990, pp. 157.
- Kesler DJ, Weston PG, Pimentel CA, Troxel TR, Vincent DL, Hixon JE: Diminution of the in vitro response to luteinizing hormone by corpora lutea induced by gonadotropin releasing hormone treatment of postpartum suckled beef cows. J. Anim. Sci. 53:749, 1981.

- Kesler DJ, Favero RJ: The effect of a sustained release injection of human chorionic gonadotropin on corpus luteum formation and progesterone secretion in beef females. Drug Development and Industrial Pharmacy, Submitted, 1995.
- Kesler DJ, Favero RJ, Troxel TR: A comparison of hydron and silicone implants in the bovine norgestomet and estradiol valerate estrus synchronization procedure. Drug Development and Industrial Pharmacy 21:475, 1995.
- Kesler DJ, Favero RJ, Ruoff WL, Troxel TR: The effect of the stage of the estrous cycle on corpus luteum function of heifers treated with Syncro-Mate B. Theriogenology 21:243, 1984.
- Kojima K, Stumpf TT, Cupp AS, Werth LA, Roberson MS, Wolfe MW, Kittok RJ, Kinder JE: Exogenous progesterone and progestins as used in estrous synchrony regimes do not mimic the corpus luteum in regulation of luteinizing hormone and 17β -estradiol in circulation of cows. Biol. Reprod. 47:1009, 1992.
- Lauderdale JW: Effects of $\text{PGF}_{2\alpha}$ on pregnancy and estrous cycle of cattle. J. Anim. Sci. 35:246, 1972.
- Lauderdale JW: The use of prostaglandins in cattle. Ann. Biol. Anim. Bioch. Biophys. 15:419, 1975.
- Lemon M: The effect of oestrogens alone or in association with progestagens on the formation and regression of the corpus luteum of the cyclic cow. Ann. Biol. Anim. Bioch. Biophys. 15:243, 1975.
- Machado R, Kesler DJ: The efficacy of norethindrone acetate and norgestomet implants on suppressing estrus in beef females. Drug Development and Industrial Pharmacy, In Press, 1995.
- McGuire WJ, Larson RL, Kiracofe GH: Syncro-Mate B[®] induces estrus in ovariectomized cows and heifers. Theriogenology 34:33, 1990.
- Moffatt RJ, Zollers WG, Welshons WV, Kieborz KR, Garverick HG, Smith MF: Basis of norgestomet action as a progestogen in cattle. Domestic Anim. Endocrinol. 10: 21, 1993.
- Odde KB: A review of synchronization of estrus in postpartum cattle. J. Anim. Sci. 68:817, 1990.
- Peters KE, Bergfeld EG, Cupp AS, Kojima FN, Mariscal V, Sanchez T, Wehrman ME, Grotjan HE, Hamernik DL, Kittok RJ, Kinder JE: Luteinizing hormone has a role in development of fully functional corpora lutea (CL) but is not required to maintain CL function in heifers. Biol. Reprod. 51:1248, 1994.

- Rajamahendran R, Taylor C: Follicular dynamics and temporal relationships among body temperature, oestrus, the surge of luteinizing hormone and ovulation in Holstein heifers treated with norgestomet. *J. Reprod. Fertil.* 92:461, 1991.
- Sanchez T, Wehrman ME, Kojima FN, Cupp AS, Bergfeld EG, Peters KE, Mariscal V, Kittok RJ, Kinder JE: Dosage of the synthetic progestin, norgestomet, influences luteinizing hormone pulse frequency and endogenous secretion of 17 β -estradiol in heifers. *Biol. Reprod.* 52:464, 1995.
- Savio JD, Thatcher WW, Badinga L, de al Sota RL, Wolfenson D: Regulation of dominant follicle turnover during the oestrous cycle in cows. *J. Reprod. Fertil.* 97:197, 1993.
- Searle GD & Company. Syncro-Mate-B®: estrus synchronizer in cattle. Freedom of Information Summary (NADA 97-037). G.D. Searle & Company, Chicago, Illinois, 1982, 16 pp.
- Sinkula AA: Methods to achieve sustained drug delivery: a chemical approach. In: Sustained and Controlled Release: Drug Delivery Systems. Ed., J.R. Robinson, Marcel Dekker, Inc., New York, NY, 1978, pp. 411.
- Troxel TR, Kesler DJ: The bovine estrous cycle: dynamics and control. Cooperative Extension Service Circular 1205, University of Illinois, Urbana, 1982, 15 pp.
- Troxel TR, Kesler DJ: Ability of indomethacin to alter prostaglandin metabolite concentrations and to enhance the function of corpora lutea induced in postpartum suckled beef cows. *J. Anim. Sci.* 59:177, 1984.
- Troxel TR, Kesler DJ, Noble RC, Carlin SE: Ovulation and reproductive hormones following steroid pretreatment, calf removal and GnRH in postpartum suckled beef cows. *J. Anim. Sci* 51:652, 1980.
- Wiseman BS, Vincent DL, Thomford PJ, Scheffrahn NS, Sargent GF, Kesler DJ: Changes in porcine, ovine, bovine and equine blood progesterone concentrations between collection and centrifugation. *Anim. Reprod. Sci.* 5:157, 1983.
- Wishart DF: Identification of steroids of high activity for control of the oestrous cycle in the dairy heifer. *J. Reprod. Fertil.* 30:333, 1972.

Table 1. The interval from SMB implant removal to estrus for heifers grouped by the day of the estrous cycle when treated with Syncro-Mate B.

Day of the Estrous Cycle	Number of Heifers	Interval from Implant Removal to Estrus ^a
3	8	44.0 ± 2.1 ^b
6	4	47.0 ± 3.0
9	8	38.5 ± 2.4
12	5	36.6 ± 3.0

^aHours from implant removal to the first detection of behavioral estrus.

^bStandard error.

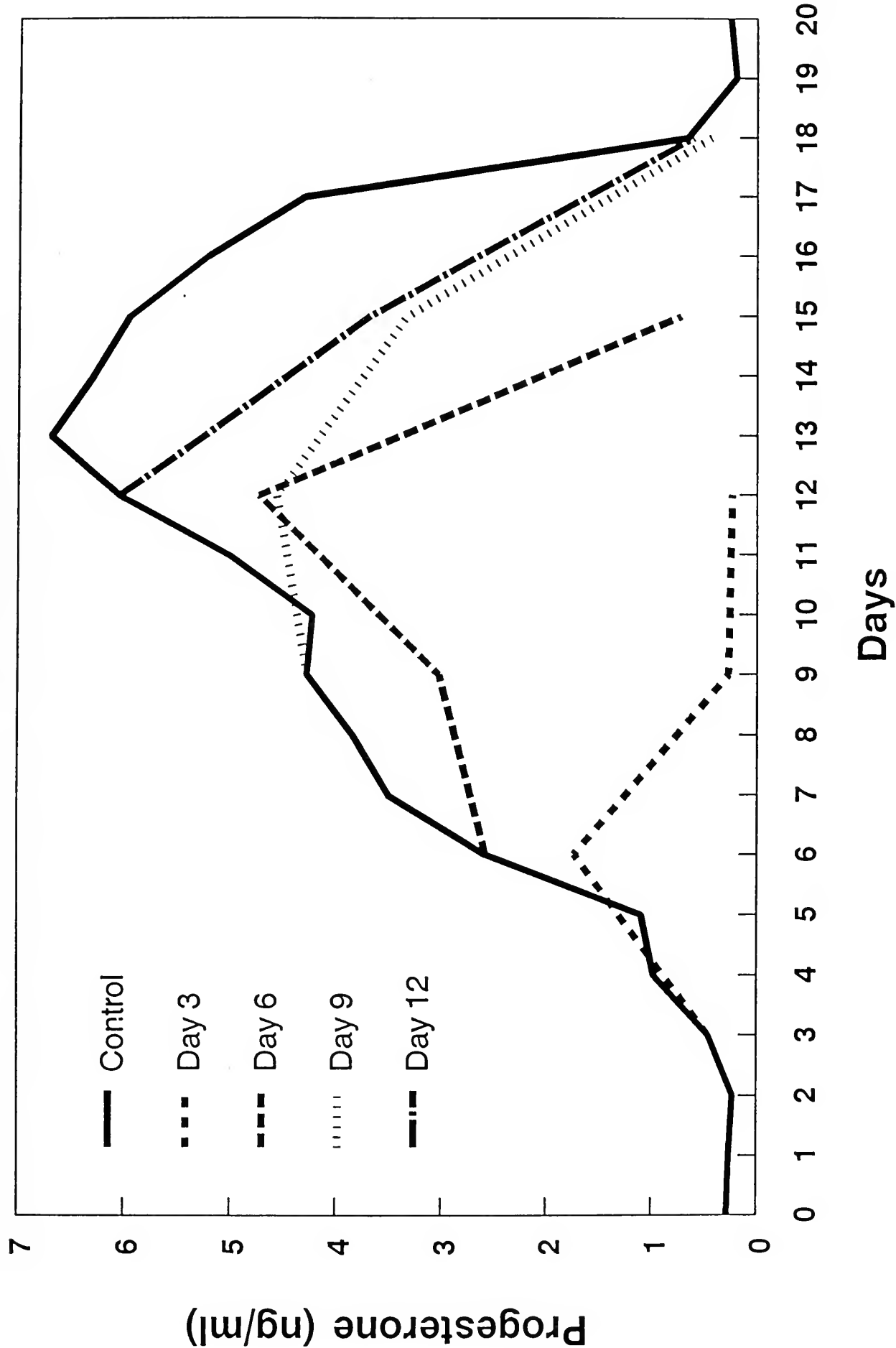


Figure 1. Progesterone concentrations in untreated heifers (solid line) from day 0 to day 20 of the estrous cycle and heifers treated with Syncro-Mate B either on day 3, 6, 9, or day 12 (broken lines) of the estrous cycle.

EFFICACY OF NORETHINDRONE ACETATE AND NORGESTOMET IMPLANTS IN SUPPRESSING ESTRUS IN BEEF FEMALES

R. Machado and D. J. Kesler

SUMMARY

Beef females with corpora lutea on day 12 of the estrus cycle were implanted with 11.5 mg norethindrone acetate implants (7 implanted and 7 non-implanted controls) at the same they were administered a luteolytic dose of prostaglandin $F_{2\alpha}$. Although the implants released 340 to 740 μg of norethindrone acetate daily, the implants did not suppress estrus. Norgestomet implants were inserted into beef females 5 days after estrus and implants were left *in situ* for 16 days. The number of cows in the norgestomet study were 27 (non-implanted), 19 (6 mg implant), and 21 (8 mg implant). Control cows were not detected in estrus until day 17 of the estrous cycle (12 days after the time of implantation) and 10 of the 27 cows (37 %) were detected in estrus over a 5 day period beginning on day 17 (12 to 16 days after the time of implantation). None of the cows implanted with 8 mg implants were detected in estrus while the implants were *in situ*. However, three of the cows with 6 mg norgestomet implants were detected in estrus 13 to 16 days post-implantation. Based on implant secretion data, cows with 6 mg implants began displaying estrus when the implants released less than 138 μg of norgestomet daily. Eight mg implants released 137 μg of norgestomet or greater per day during the entire 16 day implantation period.

INTRODUCTION

Norethindrone acetate (19-nor-17 α -ethynyl-17 β -ol-3-one acetate; figure 1) is used in combination with ethynylestradiol in the U.S. (with Food and Drug Administration [FDA] approval) as an oral contraceptive in humans. Norethindrone acetate was selected 1) because the acetate provides longer *in vivo* half-life (21), and 2) because esterification enhances steroid secretion from silicone implants (4, 9). Norethindrone acetate implants have been used efficaciously as a contraceptive (because it suppresses ovulation) in humans (14).

Norgestomet is approved by FDA for use in cattle for estrus synchronization (5). The procedure, designated Syncro-Mate B[®], includes a 9-d implant containing 6 mg of norgestomet and an intramuscular injection that consists of 3 mg of norgestomet and 5 mg of estradiol valerate that is administered at the time of implant insertion (3). The purpose of the implant is to suppress estrus and when used for estrus synchronization in cattle, subsequent timed (cattle are bred 48 to 52 hours after implant removal) breeding pregnancy rates averaged 40 % (12, 16).

Chemically, norgestomet (17 α -acetoxy-11 β -methyl-19-norpreg-4-ene-20,dione) is a modified 19-norprogesterone (figure 1). Norprogesterone is identical to progesterone except that the methyl group at the 19 position is absent. Norgestomet has two other modifications: the presence of a methyl group at the 11 position and the presence of an acetate at the 17 position. Norgestomet is metabolized quickly (15) and is excreted in the urine and feces (20). In both urine and bile, the

majority of the excreted metabolites were highly polar materials demonstrated to have only about 4% of the progestational activity of norgestomet in the Clauberg assay (20).

Norgestomet has been demonstrated to be a highly biologically active progestin. Gilbert et al. (7) reported that norgestomet was 15 times more biologically active than progesterone when orally administered to rabbits. Gilbert et. al. (7) further demonstrated that norgestomet was 216 times more biologically active than progesterone when subcutaneously administered to estradiol-17 β -treated mice. Wishart (24) demonstrated that 140 μ g of norgestomet and 45 mg of progesterone via daily intramuscular injections were required to suppress estrus in all treated heifers (which suggests that norgestomet is 321 times more potent than progesterone in this model).

The study by Wishart (24) is the only published report demonstrating the dosage of norgestomet required to suppress estrus. In that study, with a limited number of animals, norgestomet was administered via injection whereas in practice norgestomet is delivery via an ear implant to suppress estrus. Also, claims are often made that females with implants *in situ* are detected in estrus. Norethindrone acetate has not been evaluated in cattle. This study was conducted to determine 1) if norethindrone acetate would suppress estrus in cattle, and 2) the minimal dosage of norgestomet via implant delivery that efficaciously suppresses estrus in cattle.

MATERIALS AND METHODS

Experiment 1. Fourteen beef heifers were selected for the study. Heifers were divided into two groups. All heifers had been previously synchronized with prostaglandin F_{2 α} (PGF_{2 α} ; Lutalyse®; Pharmacia and Upjohn, Inc.) and observed for estrus. Twelve days after detected estrus all heifers were bled and plasma was assayed by a validated ELISA (10) for progesterone concentrations. All 14 heifers had progesterone concentrations greater than 1.5 ng/ml which suggests that they had corpora lutea that developed after the previously detected estrus. One-half (7) of the heifers were subcutaneously implanted with a norethindrone acetate matrix silicone implants. The cylindrical implants were 3.5 mm in diameter and 2.5 cm in length and were implanted subdermally on the convex surface of the ear. Each treated heifer received one implant that contained 11.5 mg of norethindrone acetate (equivalent to 8.35 mg of norethindrone). At the time of implant insertion, all heifers were injected with a luteolytic dose (25 mg) of PGF_{2 α} (Lutalyse®; 16). Implants were left *in situ* for four days and after removal, total remaining norethindrone acetate was determined (13). *In vitro* implant secretion over four days was also determined and corrected for *in vivo* secretion by a procedure reported by Kesler et al. (13).

Experiment 2. Cylindrical silicone implants impregnated with approximately 6 mg or approximately 8 mg of norgestomet were used for these studies. Implants were 2.67 mm in diameter and were 18.5 mm or 25 mm long. Quantity of norgestomet per mg of silicone was the same for both the 6 mg and the 8 mg norgestomet implants.

Four implants from each implant dose were used to determine *in vitro* secretion using the method described by Kesler et al. (13). Daily *in vitro* secretion was determined for 16 days. *In vivo* secretion and total content of norgestomet from the implants (four implants of each dosage) were also conducted as described by Kesler et al. (13).

Sixty-nine (69) postpartum beef cows were synchronized with Syncro-Mate B® (Rhone Merieux, Inc.). This synchronization protocol consisted of an intramuscular injection of 5 mg estradiol valerate and 3 mg norgestomet in sesame oil (and 10% benzyl alcohol) administered on the same day that cows were administered a 6 mg norgestomet/hydron implant on the convex surface of the ear. Implants were left *in situ* for nine days. On the fifth day after estrus, the cows were randomly assigned to three groups. Two groups were implanted with silicone implants impregnated with either 6 or 8 mg of norgestomet. These implants were subdermally implanted on the convex surface of the ear and were left *in situ* for 16 days. Twenty cows received a 6 mg norgestomet/silicone implant and 22 cows were implanted with a 8 mg norgestomet/silicone implant. Two cows lost their implant, one 6 mg implant and one 8 mg implant, and were excluded from the analysis. The other 27 postpartum beef cows were not administered a norgestomet/silicone implant. Beginning the day of implantation of the norgestomet/silicone implants, cows were observed twice daily for estrus for 31 days. Cows were considered in estrus only when they stood to be mounted by other females.

The rationale for the experimental design was as follows. First, norgestomet secretion from silicone implants (13) and the general amount of norgestomet needed to suppress estrus were known. Second, norgestomet implants have been used for re-synchronization of non-pregnant beef females previously inseminated (6). Therefore, the design was to place implants in cows during the luteal phase so that secretion from the implants was around the minimal level needed to suppress estrus when the cows would be returning in estrus.

Qualitative data were analyzed by Chi-square analysis (22).

RESULTS

Experiment 1. Norethindrone acetate was released from the silicone implants in a linearly declining fashion ($r = -.997$; $y = x [-.21] + 1.15$) (11, 13, 18). Over the four-day period, a total of 2.53 mg (22 % of the total) was delivered *in vivo*. Three of the seven control heifers (43 %) were detected in estrus whereas all seven (100 %) of the treated heifers were detected in estrus (table 1). Estrus was detected at similar times after PGF_{2α} treatment for both groups. To verify PGF_{2α}-induced luteolysis, all heifers were bled two days after PGF_{2α} treatment and plasma was assayed for progesterone concentrations (10). All heifers had progesterone concentrations suggestive that luteolysis was ensuing or had ensued in all heifers.

Experiment 2. Content of the implant was only 3.8 % higher than anticipated (table 2) and both methods of determining total *in vitro* secretion over the 16 day period produced similar results. *In vivo* secretion, however, was approximately .73 of *in vitro* secretion and was therefore *in vitro* secretion was adjusted to more truly reflect *in vivo* secretion.

The incidence of estrus behavior during the implantation period is reported in table 3. Cows implanted with 8 mg implants did not display estrus during the 16 day period. Thirty-seven percent of the non-implanted cows, however, were detected in estrus during the implantation period. More ($P < .05$) non-implanted cows were detected in estrus than 8 mg implanted cows. Cows implanted with 6 mg implants was intermediate. There tended ($P = .13$) to be fewer 6 mg

implanted cows in estrus than non-implanted cows and there tended ($P = .07$) to be more 6 mg implanted cows in estrus than 8 mg implanted cows.

As reported in tables 2 and 4, more ($P < .05$) norgestomet diffused into the serum *in vitro* for the 8 mg implants than for the 6 mg implants. The release was in a linear declining fashion as predicted for matrix type silicone implants (table 4; 11, 13, 18). Daily quantity released *in vitro* was correlated ($r = -.96$ and $r = -.94$ for 6 mg and 8 mg implants, respectively; both $P < .01$) with day *in vitro* and slopes were similar as depicted in the regression equations (table 4). Overall, approximately 49 μg more norgestomet diffused from the 8 mg implants daily than from the 6 mg implants.

Based on cows implanted with 6 mg norgestomet implants, cows began to display estrus when daily norgestomet secretion fell below 138 μg per day. Daily secretion of norgestomet from the 8 mg implants, implants that completely suppressed estrus for the 16 day implantation period, was lowest on day 16 at 137 μg per day. Therefore, it was concluded that 137 to 138 μg of norgestomet per day completely suppressed estrus in cattle.

DISCUSSION

This first evaluation of the ability of norethindrone acetate implants to suppress estrus in cattle demonstrated that it was ineffective at the 340 to 740 μg dosage per day. Levenorgesterel, a compound similar to norethindrone acetate, implants were ineffective in white-tail deer (another ruminant species; 23). Therefore, it may be that synthetic progestins that inhibit ovulation in primates are ineffective at similar dosages in ruminants. Norgestomet that suppresses estrus in cattle is also effective in white-tail deer (8).

The minimal required dose of norgestomet to suppress estrus in cattle was confirmed with silicone implant delivery of norgestomet in this study. Our study and the data of Wishart (24) would demonstrate that 137 to 140 μg of norgestomet per day will suppress estrus in cattle.

Experiments utilizing the commercial hydron (polyethylene glycomethacrylate) norgestomet implant (6 mg) have demonstrated that when it was implanted during pro-estrus, the dominant follicle present was maintained for the duration of the treatment and there was no growth of medium or small follicles (17). Systemic estradiol concentrations were also elevated, and there was insufficient progestin activity to maintain a strong negative feedback on luteinizing hormone (LH) pulse frequency in a manner comparable to that of the luteal phase of a normal estrous cycle (19). Rajamahendran and Taylor (17) suggested that this implied that the norgestomet treatment given during pro-estrus mimics the actions of low concentrations of progesterone. This time period is, in fact, a time of low norgestomet secretion by the hydron implant (13) and therefore, obtaining a low progestin effect would be expected. In fact, when implants were changed during the persistence of the dominant follicle, LH pulse frequency decreased, estradiol concentrations decreased, and follicular atresia occurred (15). Therefore, when given in appropriate amounts, norgestomet was effective in provoking the progestin-like negative feedback on LH pulse frequency and on follicular atresia.

This was supported by Butcher et. al. (2). These authors reported that daily injections of 100 mg/day was required to elevate systemic progesterone concentrations to levels of the luteal phase (5 to 7 ng/ml). Whereas, daily injections of only 45 mg/day were required to suppress estrus in all treated animals (24). The dosage selected for the norgestomet implant was based on the minimal quantity required to suppress estrus.

Fertility of ovulated persistent follicles is low (1). Therefore, the dosage of norgestomet for bovine estrus synchronization should be further evaluated and consideration given to regression of follicles rather than just on estrus suppression in order to have higher fertility rates in females treated with norgestomet for the synchronization of estrus. Kesler et al. (13), for example, used an implant with more norgestomet release and had improved synchronized fertility rates.

REFERENCES

- Anderson, L.H. and M.L. Day. 1994. Acute progesterone administration regresses persistent dominant follicles and improves fertility of cattle in which estrus was synchronized with melengestrol acetate. *J. Anim. Sci.* 72:2955-2961.
- Butcher, R.L., J.E. Reber, A.W. Lishman, K.F. Breuel, F.N. Schrick, J.C. Spitzer, and E.K. Inskeep. 1992. Maintenance of pregnancy in postpartum beef cows that have short-lived corpora lutea. *J. Anim. Sci.* 70:3831-3837.
- Chien, Y.E. 1978. Methods to achieve sustained drug delivery. A physical approach: implants. In: Robinson, J.R. (ed.). *Sustained and Controlled Release Drug Delivery Systems*. Marcel Dekker, Inc., New York. pp. 326-327.
- Christensen, D.A. and D.J. Kesler. 1984. Passage of testosterone, testosterone propionate and testosterone enanthate from silastic implants and the retention of testosterone once it enters the blood of ewes. *Anim. Reprod. Sci.* 7:531-536.
- Darling, Lisa. 1993. *Veterinary Pharmaceuticals and Biologicals*. Veterinary Medicine Publishing Co., Lenexa, Kansas. p. 892.
- Favero, R.J., D.B. Faulkner, and D.J. Kesler. 1993. Norgestomet implants synchronize estrus and enhance fertility in beef heifers subsequent to a timed artificial insemination. *J. Anim. Sci.* 71:2594-2600.
- Gilbert, H.G., G.H. Phillipps, A.F. English, L. Stephenson, E.A. Woollett, C.E. Newall, and K.J. Child. 1974. The progestational and anti-estrogenic activities of some novel 11 β -substituted steroids. *Steroids* 23: 585-602.
- Kesler, D.J. 1995. Remotely-delivered contraception with needle-less norgestomet implants. In: Kreeger, T.J. (ed.). *Contraception in Wildlife Management*. (In Press).

- Kesler, D.J. 1989. Novel approaches and applications of steroid hormone delivery via polydimethylsiloxane. In: Gebelein, C.G., and R.L. Dunn (eds.). Applied Bioactive Polymeric Materials. Plenum Press, New York. pp. 125-138.
- Kesler, D.J., H. Khazali, and R.J. Favero. 1990. Quantification of steroids via a polymér linked second antibody enzyme immunoassay system: methods of linking anti-rabbit IgG to poly(styrene). In: Gebelein, C.G., and R.L. Dunn (eds.). Progress in Biomedical Polymers. Plenum Press, New York, NY. pp. 157-170.
- Kesler, D.J. and R.J. Favero. 1989. In vitro and in vivo secretion of norgestomet from matrix silicone and hydron implants and pregnancy rates of females synchronized with norgestomet. In: Pearlman, R. and J.A. Miller (eds.). Proc. Int. Symp. Controlled Release Bioactive Materials. Controlled Release Soc., Lincolnshire, Illinois. pp. 435-436.
- Kesler, D.J. and R.J. Favero. 1995. Estrus synchronization in beef females with norgestomet and estradiol valerate. Part 2: Factors limiting and enhancing efficacy. Agri-Practice 17:12-17.
- Kesler, D.J., R.J. Favero, and T.R. Troxel. 1995. A comparison of hydron and silicone implants in the bovine norgestomet and estradiol valerate estrus synchronization procedure. Drug Development and Industrial Pharmacy 21:475-485.
- McCauley, A.P. and J.S. Geller. 1992. Decisions for norplants programs. In: Goldstein, S.M. (ed.). Population Reports (Series K, No. 4). Population Information Program, The Johns Hopkins University, Baltimore, Maryland. 31 pp.
- Moffett, R.J., W.G. Zollers, Jr., W.V. Welshons, K.R. Kieborz, H.A. Garverick, and M.F. Smith. 1993. Basis of norgestomet action as a progestogen in cattle. Domestic Anim. Endocrinol. 10:21-30.
- Odde, K.G. 1990. A review of synchronization of estrus in postpartum cattle. J. Anim. Sci. 68:817-830.
- Rajamahendran, R. and C. Taylor. 1991. Follicular dynamics and temporal relationships among body temperature, oestrus, the surge of luteinizing hormone and ovulation in Holstein heifers treated with norgestomet. J. Reprod. Fertil. 92:461-467.
- Roseman, T.J. 1972. Release of steroids from a silicone polymer. J. Pharm. Sci. 61:46-50.
- Savio, J.D., W.W. Thatcher, L. Badinga, R.L. de la Sota, and D. Wolfenson. 1993. Regulation of dominant follicle turnover during the oestrous cycle in cows. J. Reprod. Fertil. 97:197-203.

- Searle, G.D. & Company. 1982. Syncro-Mate-B®: estrus synchronizer in cattle. Freedom of Information Summary (NADA 97-037). G.D. Searle & Company, Chicago, Illinois. 16 pp.
- Sinkula, A.A. 1978. Methods to achieve sustained drug delivery. In: Robinson, J.R. (ed.). Sustained and Controlled Release Drug Delivery Systems. Marcel Dekker, Inc., New York, NY. pp. 411-543.
- Steel, R.G.D. and J.H. Torrie. 1960. Principles and Procedures of Statistics. McGraw-Hill, New York, NY (1960).
- White, L.M., R.J. Warren, and R.A. Fayrer-Hosken. 1994. Levenorgesterel implants as a contraceptive in captive white-tailed deer. J. Wild. Dis. 30:241-246.
- Wishart, D.F. 1972. Identification of steroids of high activity for control of the oestrous cycle in the dairy heifer. J. Reprod. Fertil. 30:333-334.

Table 1. Norethindrone acetate implant secretion and estrus suppression efficacy in beef heifers.

Item	Control	Treated
Number	7	7
Number in estrus	3 (43%)	7 (100%) ^a
Mean interval to estrus	61 hours	59 hours
Norethindrone acetate secreted:		
day 1	0	947 µg
day 2	0	738 µg
day 3	0	501 µg
day 4	0	341 µg

^aDiffered from the control group at the .02 level of significance.

Table 2. Content (mg), and in vivo and in vitro secretion (mg) of norgestomet from 6 mg and 8 mg silicone implants.

Item	Norgestomet Implants	
	6 mg	8 mg
Content (mg)	6.21	8.33
<u>In vivo</u> secretion ^a	3.04	3.76
<u>In vitro</u> secretion:		
Method 1 ^a	4.19	5.18
Method 2 ^b	4.01	5.46
<u>In vivo</u> / <u>In vitro</u> ratio	.73	.73

^aContent minus content remaining after 16 days in situ or in vitro.

^bCumulative in vitro secretion observed during the 16 days in vitro.

Table 3. Incidence of estrus during implantation with norgestomet implants.

Days After Estrus	Norgestomet		
	6 mg	8 mg	Non-Implanted
16	0	0	0
17	0	0	1
18	1	0	4
19	0	0	2
20	1	0	1
21	1	0	2
Combined	3/19 ^a	0/21 ^b	10/27
Combined %	16 %	0 %	37 %

^aTends to differ ($P = .13$) from non-implanted cows and tends to differ ($P = .07$) from 8 mg implanted cows.

^bDiffers ($P < .01$) from non-implanted cows and tends to differ ($P = .07$) from 6 mg implanted cows.

Table 4. Daily norgestomet secretion^a by 6 and 8 mg implants as related to estrus suppression.

6 mg Implants		8 mg Implants	
Day	μg Norgestomet ^b	μg Norgestomet ^c	Day
		329	1
		316	2
		303	3
		290	4
1	281	278	5
2	267	264	6
3	255	252	7
4	242	239	8
5	229	227	9
6	216	214	10
7	203	201	11
8	190	188	12
9	177	175	13
10	164	162	14
11	151	150	15
12	138	137	16 ^d
13	125		
14	112		
15	99		
16	86		

^aAdjusted to reflect daily *in vivo* secretion.

^bDaily corrected secretion (Y) based on the following regression equation ($r = -.96$).
 $Y = -17.8059 X + 402.2250$

^cDaily corrected secretion (Y) based on the following regression equation ($r = -.94$).
 $Y = -17.5603 X + 468.3250$

^dNo cows were detected in estrus for the days above the line. For the 6 mg implant one cow was detected in estrus on day 13, one on day 15, and one on day 16. Implants were removed on day 16 for both 6 mg and 8 mg implants.

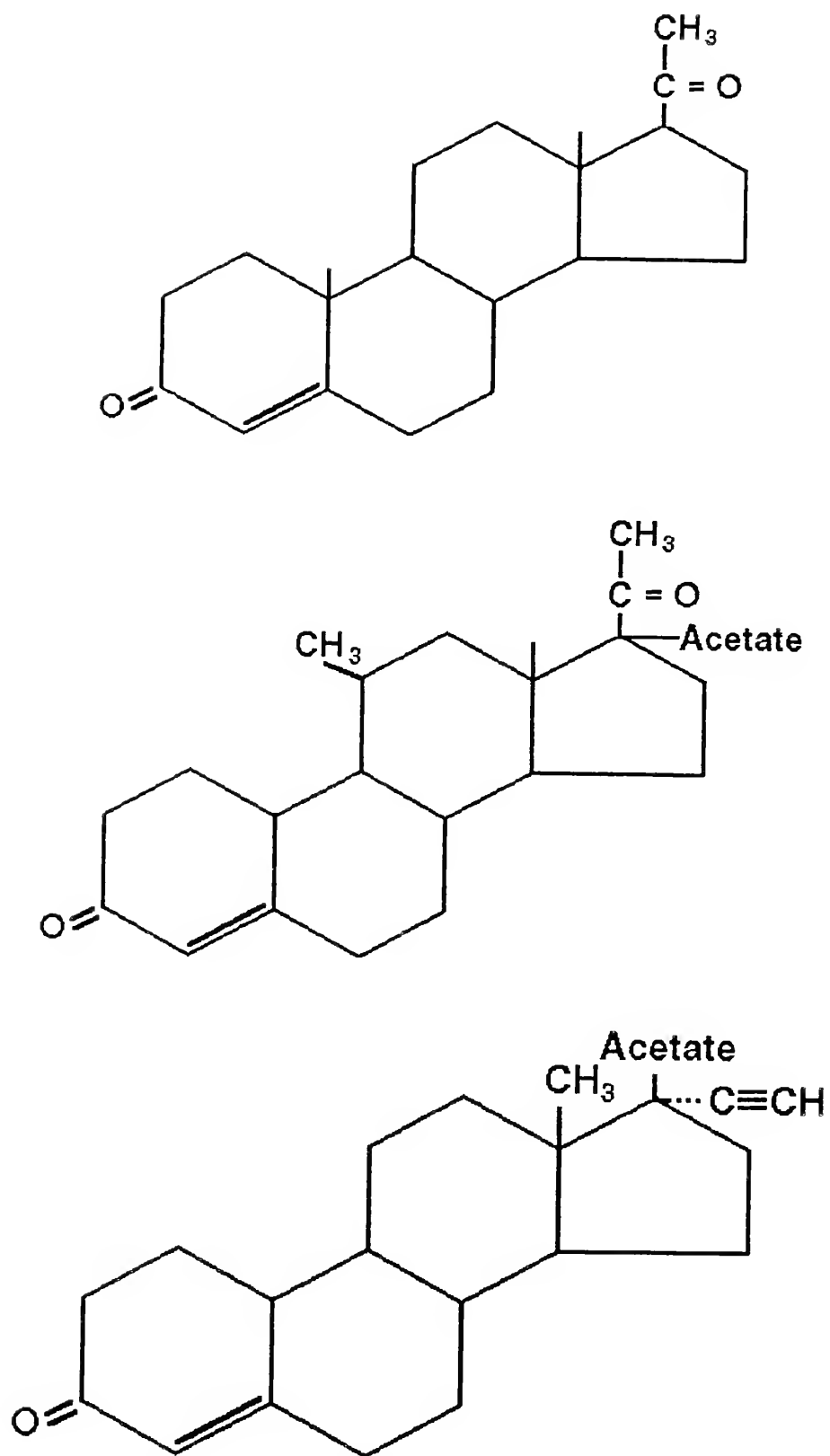


Figure 1. Chemical structures of progesterone (top), norgestomet (middle), and norethindrone acetate (bottom).

EFFECT OF CONSTANT DELIVERY OF GONADOTROPIN RELEASING HORMONE ON FERTILITY OF CATTLE

R. J. Favero, L. C. Cruz, and D. J. Kesler

SUMMARY

Four hundred and three (403) postpartum beef cows, synchronized with the norgestomet and estradiol valerate bovine estrus synchronization procedure, were included in three experiments. In the first experiment, 78 of the 178 cows were administered biodegradable microcapsules containing 180 μg GnRH manufactured to biodegrade (and release GnRH relatively constantly) in approximately three days. In the second experiment, 38 of the 90 cows were implanted with osmotic pumps designed to deliver 2.5 μg of GnRH per hour for six days. The third experiment consisted of two trials. In the first trial, 21 of the 41 cows were implanted with biodegradable implants manufactured to delivery 250 μg of GnRH (relatively constantly) over a four day period. In the second trial, 46 of the 94 cows were implanted with same implant as in trial 1 except the implants were coated so that there was a slight delay in initiating delivery after implantation. The constant delivery of GnRH during the proestrus period reduced pregnancy rates when GnRH was administered via osmotic pumps, microcapsules, and implants. Constant delivery implants with a delay in release after implantation, however, had no effect on pregnancy rates. In summary, constant delivery of GnRH, via all of the delivery systems, was not considered a valid method of enhancing fertility in proestrus cattle.

INTRODUCTION

Various programs have been developed to synchronize estrus in beef females. Estrus synchronization programs can be separated into two categories: luteolytic agents or combinations of progestins and luteolytic/anti-luteotropic agents. Programs using luteolytic agents (prostaglandin $\text{F}_{2\alpha}$; $\text{PGF}_{2\alpha}$) hasten estrus in females with mature corpora lutea (day 5 or greater of the estrous cycle). The problems with $\text{PGF}_{2\alpha}$ are it's ineffectiveness in anestrus females and the variable interval from injection to estrus. Therefore, estrus detection or two timed artificial inseminations are required to achieve acceptable pregnancy rates (8).

Programs utilizing progestins and luteolytic/anti-luteotropic agents are effective in inducing ovulation in anestrus females and have more predictable intervals from progestin withdrawal to estrus allowing for a single timed artificial insemination. Hixon et al. (4) found that following the Syncro-Mate B (SMB) treatment (7), 60% of the cows included in the study experienced spontaneous preovulatory luteinizing hormone (LH) surges 30 to 34 hours after implant removal. Also the administration of gonadotropin releasing hormone (GnRH) between the time of norgestomet implant removal and timed artificial insemination, during the anticipated time of the LH surge, has been shown to increase pregnancy rates in females treated with norgestomet and $\text{PGF}_{2\alpha}$ (10, 11, 12). However, this program required additional animal handlings. Troxel et al. (10) treated cows with the conventional SMB procedure followed by GnRH 30 hours after implant removal and this procedure increased the pregnancy rate in both cyclic and anestrus GnRH

treated beef cows, but again required additional animal handlings for treatments as compared to SMB alone.

Capel et al. (2) demonstrated that luteal activity could be induced in anestrus cows by administration of GnRH (0.5 to 2.5 $\mu\text{g}/\text{hour}$) either by constant infusion or by pulses every 2 hours with a total treatment duration of 48 hours. Similarly Bishop et al. (1) were able to overcome a nutritionally induced anestrus in beef cows by pulsatile infusion of GnRH at a rate of 0.5 to 2.0 μg GnRH per hour.

The purpose of the experiments reported herein were to investigate the effect of GnRH administered in constant release formulations at low levels beginning at the time of norgestomet implant removal. Previous experiments in this laboratory have demonstrated the efficacy of GnRH administration to synchronized cows between the time of norgestomet implant removal and artificial insemination. Administration of GnRH in manners similar to those reported herein would allow the administration of GnRH, without increasing the number of animal handlings.

MATERIALS AND METHODS

Three experiments with crossbred beef females maintained at the Dixon Springs Agricultural Center at Simpson, IL.

Experiment 1. One hundred and seventy eight (178) cows were synchronized with SMB. The SMB (Rhone Merieux, Inc.) treatment consists of an intramuscular injection of norgestomet (3.0 mg) and estradiol valerate (5.0 mg) in sesame oil/benzyl alcohol and a hydron ear implant that contains 6.0 mg norgestomet. The implant was subcutaneously inserted into the convex surface of the middle or distal one-third of the ear. At the end of 9 days the norgestomet implants were removed. At SMB implant removal cows were assigned to one of two groups. Seventy-eight (78) of the cows were administered biodegradable microcapsules containing GnRH. The other one hundred (100) cows served as controls. There were fewer cows in the treated group than the control group because of a limited availability of microcapsules. The microcapsules consisted of GnRH entrapped in poly (DL-lactide-co-glycolide) by a phase separation process. They were sterilized with gamma irradiation and stored in a free-flowing powder of spherical particles at room temperature until used. For injection, the microcapsules were suspended in a solution of 2 % (by weight) carboxymethylcellulose and 1 % (by weight) tween 20 in saline. Each treated cow received a single intramuscular injection of 100 mg of microcapsules containing 180 μg of GnRH. All females were artificially inseminated approximately 48 hours after SMB implant removal.

Experiment 2. Ninety (90) cows were synchronized with SMB. At the time of implant removal the cows were assigned to one of two groups. Thirty eight (38) of the cows were implanted with osmotic pumps containing GnRH. The remaining cows ($n = 52$) served as controls and received no further treatment. There were fewer cows in the treated group than the control group because of a limited availability of osmotic pumps. The GnRH was administered at a rate of approximately 2.5 $\mu\text{g}/\text{hr}$ for 6 days via primed osmotic pumps (Alzet; model 2001). The osmotic pumps were primed by placing them in a room temperature (21°C) saline solution for 12 hours

prior to administration to the animal. By being primed in this manner, the osmotic pumps began delivering GnRH upon implantation. The osmotic pumps were subcutaneously implanted over the rib cage at the time of SMB implant removal. All cows were artificially inseminated approximately 48 hours after SMB implant removal.

The osmotic pumps were surgically implanted without anesthesia with a scalpel, a hemostat to separate the skin from the subcutaneous tissue, and a suture was used to close the wound. The implantation area was cleaned and disinfected both immediately before and after implanting the osmotic pumps. Osmotic pumps were surgically removed with a scalpel after cleaning and disinfecting the area.

Experiment 3. Experiment 3 consisted of two trials with cows synchronized with SMB. In trial 1, 41 cows were divided into two groups after SMB implants removal. Twenty one (21) of the cows were administered a GnRH implant and twenty (20) served as controls. The GnRH implant was subcutaneously implanted on the convex surface of the ear with a trocar. Implants contained 250 μg of GnRH in a biodegradable lipid based matrix that eroded relatively constantly, making GnRH available, over approximately 4 days. All females were artificially inseminated approximately 48 hours after SMB implant removal. In trial 2, ninety four (94) cows were assigned to one of two groups. Forty-six (46) of the cows were administered a GnRH implant and the remaining forty-eight (48) served as controls. The GnRH implants were subcutaneously implanted on the convex surface of the ear with a trocar. The implants were identical to those used in trial 1 except they were coated so that there was a slight delay in initiating delivery after implantation. The outer layer did not contain GnRH and only after erosion of that layer was GnRH capable of being released. All females were artificially inseminated approximately 48 hours after SMB implant removal.

Six days following artificial insemination the females from all studies and all treatment groups were exposed to bulls for the remainder of the 63 day breeding season. Calving rates to the various treatments were based on calving dates the following calving season. Comparisons of calving rate were made between the GnRH treated groups and the control groups using Chi-square analysis (3).

RESULTS AND DISCUSSION

We hypothesized that the constant delivery of GnRH to cattle during the proestrus interval from SMB implant removal to artificial insemination would enhance fertility. In consideration of future application it was decided to use biodegradable microcapsules first because of their ease of delivery and the extensive development work previously conducted. Upon obtaining the results from experiment 1 and from data that was subsequently published about the microcapsules, we then decided to test the hypothesis with an established constant delivery system: osmotic pumps. However, again based on results from experiment 2 and more data from the literature we made one last attempt and conducted experiment 3.

In experiment 1, the administration of GnRH microcapsules decreased ($P < .05$) synchronized pregnancy rates. In data published elsewhere we demonstrated that the non-encapsulated GnRH

or the GnRH in the outer layers of the microcapsules that was released soon after administration triggered a preovulatory LH surge (6). The stores of LH in the anterior pituitary gland were then depleted and the anterior pituitary was incapable of synthesizing enough LH for another LH surge at the appropriate time to induce a synchronized ovulation.

In the second experiment, the administration of GnRH via osmotic pumps tended to decrease ($P = .08$) synchronized pregnancy rates. Other investigators (9) working with the same hypothesis demonstrated that the GnRH treatment initiated a premature preovulatory-like LH surge which peaked $7.2 \pm .5$ hours following the initiation of GnRH treatment.

One possible reason for the decrease in fertility that was encountered when osmotic pumps were used, might be because of the pliable nature of the external case of the pre-incubated osmotic pumps. The osmotic pumps were inserted by grasping them with forceps and inserting the pump into a small incision in the skin. During this process the outer walls of the osmotic pumps may have been compressed and this increased pressure may have caused the release of a small volume (but high concentration) of GnRH. This GnRH could have been enough to cause the premature LH surge that was described earlier. Further, variability in delivery from osmotic pumps has been previously observed (5).

In order to understand these results, the authors developed a novel lipid based ear implant that delayed release of GnRH for a few hours after administration. The implant was manufactured so that there was an outer layer that did not contain GnRH. After, and only after, erosion of that layer was GnRH capable of being released. Results from trial 2 of experiment 3 demonstrate that when the initial release of GnRH was eliminated there was no longer a detrimental effect ($P > .25$) of GnRH on synchronized pregnancy rates. If the coating that delayed release was not included, pregnancy rates were decreased ($P < .05$) as for the microcapsules and for the osmotic pumps. However, even though the technical problem of reduced fertility was corrected, our original hypothesis that a constant delivery of GnRH would enhance fertility in proestrus cattle was incorrect and the concept was abandoned.

REFERENCES

- Bishop, D.K., R.P. Wetteman, and C.M. O'Connell. Pulsatile infusion of GnRH initiates luteal activity in nutritional anestrous beef cows. *J. Anim. Sci.* **68** (Suppl. 1):416 (1985).
- Chapel, J.P., A.R. Peters, and G.E. Lamming. Pulsatile vs continuous infusion of GnRH to induce LH release in the post-partum beef cow. *Tenth Int. Cong. Anim. Reprod. AI*, 2:6 (1984).
- Cochran, W.G., and G.M. Cox. *Experimental Designs* (2nd ed.). John Wiley and Sons, New York, NY (1957).
- Hixon, D.L., D.J. Kesler, T.R. Troxel, D.L. Vincent, and B.S. Wiseman. Reproductive hormone secretions and first service conception rate subsequent to ovulation control with Syncro-Mate B. *Theriogenology* **16**:219-229 (1981).

- Kesler, D.J., L.C. Cruz, and J.A. McKenzie. The effect of constant delivery of GnRH on the episodic secretion of equine LH. *J. Cont. Release* **8**:55-61 (1988).
- Kesler, D.J., L.C. Cruz, J.A. McKenzie, and E.A. Henderson. The effect of the GnRH burst release on the efficacy of GnRH microcapsules. *Proc. 13th Int. Symp. Cont. Rel. of Bioactive Materials*, pp. 54-55 (1986).
- Kesler, D.J., R.J. Favero, and T.R. Troxel. A comparison of hydron and silicone implants in the bovine norgestomet and estradiol valerate estrus synchronization procedure. *Drug Development and Industrial Pharmacy* **21**:475-485 (1995).
- Lauderdale, J.W., B.E. Sequin, J.N. Stellflug, J.R. Chenault, W.W. Thatcher, C.K. Vincent and A.F. Loyancano. Fertility of cattle following PGF₂ α injection. *J. Anim. Sci.* **38**:964-967 (1974).
- McVey, W.R. and G.L. Williams. Effects of temporary calf removal and osmotic pump delivery of gonadotropin-releasing hormone on synchronized estrus, conception to a timed artificial insemination and gonadotropin secretion in norgestomet-estradiol valerate-treated cattle. *Theriogenology* **32**:969-978 (1989).
- Troxel, T.R., L.C. Cruz, R.S. Ott, and D.J. Kesler. Norgestomet and gonadotropin releasing hormone enhance corpus luteum function and fertility of postpartum suckled beef cows. *J. Anim. Sci.* **71**:2579-2585 (1993).
- Valle, E.R., L.C. Cruz, G.F. Cmarik, R.S. Ott, L.A. Peterson, and D.J. Kesler. The effect of GnRH and its method of administration on ovulation response, corpus luteum function and fertility of beef heifers synchronized with norgestomet and PGF₂ α . *J. Anim. Sci.* **63** (Suppl. 1):132-133 (1986).
- Valle, E.R., L.C. Cruz, G.F. Cmarik, R.S. Ott, L.A. Peterson, and D.J. Kesler. The effect of short term calf removal, GnRH and its method of administration on ovulation response, corpus luteum function and fertility of postpartum suckled beef cows synchronized with norgestomet and PGF₂ α . *J. Anim. Sci.* **63** (Suppl. 1):132 (1986).

Table 1. The effect of continuous administration of gonadotropin releasing hormone (GnRH) on pregnancy rates.

Implant	Untreated	GnRH Treated
Experiment 1: Biodegradable Microcapsules	18/100 (18%) ^a	6/ 78 (8%) ^b
Experiment 2: Osmotic pumps	13/ 52 (25%) ^c	4/ 38 (11%) ^d
Experiment 3: Biodegradable Implants-1 ^e	7/ 20 (35%) ^a	2/ 21 (10%) ^b
Biodegradable Implants-2 ^f	17/ 48 (35%)	13/ 46 (28%)

^{a,b}Groups with different superscripts differ ($P < .05$).

^{c,d}Groups with different superscripts tended to differ ($P = .08$).

^eImplants were manufactured to release GnRH upon implantation.

^fImplants were manufactured to have a delay in releasing GnRH after implantation.

GONADOTROPIN RELEASING HORMONE ENHANCES THE CALVING RATE OF BEEF FEMALES ADMINISTERED NORGESTOMET AND PROSTGLANDIN F_{2α} FOR ESTRUS SYNCHRONIZATION

E. R. Valle, L. C. Cruz, and D. J. Kesler

SUMMARY

One hundred and fifty beef heifers and 403 beef cows suckling calves were administered norgestomet implants (8 d) and PGF_{2α} approximately 28 h before implant removal. Thirty hours after implant removal, females were administered either GnRH via injection, GnRH via implantation, or no GnRH. The dosage of GnRH was 250 µg and implants prolong the induced LH surge. Ovulation response, incidence of short cycles, and calving rate were analyzed as a 2 X 2 X 3 completely randomized factorial design with female (heifers and cows), estrous cycles (with or without before PGF_{2α}), and GnRH as the main effects. There were no interactions ($P > .10$), and because heifers and cows had responses that did not differ ($P > .25$), they were summarized together. Females with estrous cycles had a higher ($P < .05$) ovulation response, fewer ($P < .01$) short luteal phases, and a higher ($P < .01$) calving rate than females without estrous cycles. GnRH treatment increased the ovulation response ($P < .01$) and the calving rate ($P < .05$) and these responses were not effected ($P > .10$) by the method of GnRH administration. Based on this data, the increased ovulation response to GnRH may account for 29% of the increase in calving rate observed in the GnRH treated females. In summary, in norgestomet and PGF_{2α} synchronized females, GnRH enhanced calving rate regardless of how it was administered. This increase was due to more than an increased ovulation rate.

INTRODUCTION

Although several estrus synchronization procedures have been developed, most require that synchronized females be bred over several days at estrus (Odde, 1990 for review). The only procedure that permits AI at a single predetermined time utilizes a norgestomet implant and an injection of a luteolytic or an anti-luteotropic compound (Odde, 1990; Kesler and Favero, 1995). Pregnancy rates of cattle synchronized with these types of products, however, have been variable because of asynchronized ovulations and short luteal phases (Kesler and Favero, 1996).

It was previously demonstrated that the administration of GnRH 30 h after norgestomet implant removal enhanced timed AI pregnancy rates (Troxel et al., 1993). However, GnRH was administered via various methods in those trials and the GnRH-induced preovulatory LH surge has been demonstrated to effect factors (ovulation and short luteal phases) that reduce synchronized fertility (Kesler et al., 1987). Therefore, the objective of this experiment was to determine the effectiveness of administering GnRH (via injections and implants, which prolong the induced LH surge) 30 h after norgestomet implant removal on enhancing the calving rate of beef heifers and cows.

MATERIALS AND METHODS

One hundred and fifty cross-bred beef heifers and 403 cross-bred beef cows suckling calves from the Dixon Springs Agricultural Center were used. The heifers were 12 to 15 mo of age and the cows were 3 to 12 y of age. Calving occurred from February through April and the number of d postpartum at the timed AI ranged from 42 to 89 d with an mean of $63.6 \pm .8$ d. All females were managed similarly and were grazed on fescue pasture and supplemented with alfalfa hay and corn silage during the winter.

All females received a subcutaneous ear implant containing 6 mg norgestomet and an intramuscular injection of 5 mg of the $\text{PGF}_{2\alpha}$ analogue alfaprostol (Jochle et al., 1982; Maffeo et al., 1983) approximately 28 h before implant removal (Fig. 1). The alfaprostol was dissolved in propylene glycol at 1 mg/mL and 5 mL was injected via 16 g needles. The implants were implanted on the convex surface of the ears. At the time of norgestomet implantation, females were randomly assigned to receive no GnRH, GnRH via injection, or GnRH via implant. GnRH was administered approximately 30 h after norgestomet implant removal, approximately 58 hours after the injection of $\text{PGF}_{2\alpha}$ (Fig. 1). All females were artificially inseminated once approximately 18 h after the time of GnRH administration. Eighteen days after the timed AI bulls were included with the females for 62 d. The semen used at the timed AI was from bulls of known fertility and of different breeds than the bulls used for natural service. Semen from multiple sires was used, and service sire selection was made before the timed AI and before the cows were completely randomly allotted to treatment groups. Calving rate was determined the next calving season and was based on the phenotype of the offspring.

The GnRH implants were manufactured as described by Troxel et al. (1993) and were implanted behind the shoulder of the treated females. A small incision was made through the skin with a scalpel, and the implant was inserted with the assistance of hemostats. A small amount of antibiotic was applied to the implant insertion site. For the injection, GnRH was dissolved in a potassium phosphate buffer at a concentration of 50 $\mu\text{g/mL}$, and 5 mL was administered in the upper rear leg musculature. Previous data (Kesler and Vincent, 1980; Troxel et al., 1983) have demonstrated that administration of GnRH via implants used herein induces a LH surge of similar magnitude and duration to a spontaneous preovulatory LH surge (Helmer and Britt, 1987).

Blood samples were collected via jugular venipuncture into heparinized evacuated tubes 11 d before norgestomet implantation, before norgestomet implantation, before $\text{PGF}_{2\alpha}$, before the time of GnRH, and on d 5 or 6 and d 14 or 15 after the time of GnRH treatment. After collection, blood samples were placed in an ice water bath and within 6 h after collection centrifuged at 2,500 x g for 15 min (Wiseman et al., 1983). The plasma was transferred to vials and stored at -20°C until assayed for progesterone concentrations. Blood samples were assayed for progesterone concentrations using a validated progesterone ELISA (Kesler et al., 1990). Intraassay and interassay coefficients of variation were 8.3% and 11.7%, respectively.

Females with progesterone concentrations ≥ 1.0 ng/mL in one or more of the blood samples collected before $\text{PGF}_{2\alpha}$ were considered to be with estrous cycles whereas if all blood samples before $\text{PGF}_{2\alpha}$ had < 1.0 ng/mL of progesterone, females were not considered with estrous cycles.

The females with blood progesterone concentrations ≥ 1.0 ng/mL at the time of GnRH were considered not synchronized to the norgestomet and PGF_{2 α} . This included 20 females, and these females were eliminated from the groups before analysis. The blood samples collected 5 or 6 and 14 or 15 d after the time of GnRH treatment were used to determine ovulation response and subsequent corpus luteum function. Synchronized females that had progesterone concentrations ≥ 0.5 ng/mL on d 5 or 6 after the time of GnRH treatment were considered to have ovulated following the time of GnRH treatment. Females that ovulated and had ≥ 1.0 ng/mL of progesterone on d 14 or 15 were considered to have normal luteal phases whereas those with < 1.0 ng/mL of progesterone were considered to have short luteal phases. These classifications were previously described and determined to be adequate methods of detecting ovulation and short luteal phases by Kesler et al. (1981).

Ovulation response, the incidence of short luteal phases, and calving rate to the timed breedings were analyzed by analysis of variance (Hicks, 1964). The model was a 2 X 2 X 3 factorial with female (heifer and cow), estrous cycles (with or without), and GnRH (untreated, injected, and implanted) as the main effects and were analyzed as a completely randomized design (Steel and Torrie, 1980). Differences among the three GnRH treatments were determined if the main effect was significant ($P \geq .05$) with the F-test Protected Least Significant Difference method (Carmer and Swanson, 1973). Since the main effect female was not significant ($P > .25$) for any of the analyses, heifers and cows were summarized together. Also, no interactions were significant ($P > .10$) for any of the analyses and, therefore, only the main effects, estrous cycles and GnRH, are discussed in detail.

RESULTS

More ($P < .05$) females with estrous cycles (95%) than females without estrous cycles (90%) ovulated subsequent to treatments. After synchronization, 85% of the females that did not receive GnRH ovulated whereas 96 to 97% of the GnRH treated females ovulated ($P < .01$); Table 1). The ovulation response between the two methods of GnRH administration were not different ($P > .10$). Although the incidence of short luteal phases was lower ($P < .01$) for females with estrous cycles (2%) than for females without estrous cycles (8%), GnRH had no effect ($P > .10$) on the incidence of short luteal phases (Table 2).

Females with estrous cycles (48%) had a higher ($P < .01$) calving rate than females without estrous cycles (30%). GnRH treated females had a higher ($P < .05$) calving rate than females that received no GnRH treatment (Table 3). The calving rate between the two methods of GnRH administration were not different ($P > .10$). None of the 41, 26, and 20 females that did not ovulate, had short luteal phases, and were not synchronized by the norgestomet and PGF_{2 α} , respectively, calved to the timed AI. Based on this data, the increased ovulation rate of GnRH treated females may account for 37% and 21% of the increased calving rate for the females without and with estrous cycles, respectively.

DISCUSSION

There are several methods to synchronize estrus in beef females (Odde, 1990 for review). Although only one method was used in this study, the concurrent use of norgestomet and alfaprostol and Syncro-Mate B have similar efficacy (Beal et al., 1984; Whittier et al., 1986). The PGF_{2α} analogue alfaprostol, like natural PGF_{2α}, lyses corpora lutea 5 d and greater beyond estrus (Kiracofe et al., 1985). However, because the interval from alfaprostol to estrus is 48 to 84 h, it must be administered 1 d before removal of a norgestomet implant, that had been left *in situ* for at least 5 d, in order for females to be synchronized for a single predetermined breeding (Heersche et al., 1979). Because more handlings are required with the norgestomet and PGF_{2α} procedure, Syncro-Mate B would be more advantageous.

Two factors that reduce synchronized fertility are asynchronized ovulations, particularly if females are bred at a predetermined time, and short luteal phases (Kesler and Favero, 1996). Studies, with limited numbers of females, have demonstrated that GnRH enhanced fertility if administered approximately 30 h after norgestomet implant removal, approximately 18 h before timed AI (Troxel et al., 1993; Hoffman et al., 1995). One of the two studies conducted by Troxel et al. (1993) used a large number of females; however, calving rate was abnormally low for the non-GnRH treated females (Kesler and Favero, 1996).

The characteristics of GnRH induced LH surges via injection have been demonstrated to be atypical of preovulatory LH surges at estrus even when more potent GnRH analogues were used (Chenault et al., 1990). Kesler et al. (1987) and Vincent and Kesler (1985) demonstrated that fewer females with GnRH-induced LH surges atypical of spontaneous preovulatory LH surges ovulated and more had short luteal phases. Although the required LH surge profile to induce ovulation in primates differs from domestic animals, Zelinski-Wooten et al. (1991) demonstrated a similar phenomena in primates. The most important aspect of the LH surge that was necessary for ovulation and normal luteal function observed in both species was that the duration of the LH surge be of similar duration to a spontaneous preovulatory LH surge (Kesler et al., 1987; Zelinski-Wooten et al. 1991).

Ramirez-Godinez et al. (1982) reported that FSH concentrations were lower prior to an early weaning induced first postpartum ovulation than prior to a subsequent ovulation. Lishman et al. (1979) administered FSH to cows prior to GnRH treatment and observed that a greater proportion of cows injected with FSH ovulated than non-FSH treated cows. Therefore, in addition to the duration of the induced LH surge, there may be a relationship between FSH and the incidence of induced ovulations.

Although GnRH was administered by injection and implants in the study by Troxel et al. (1993), they were in separate studies, and it was not possible to determine the effect of the method of GnRH administration. Data from this study demonstrate that method of GnRH administration was unimportant. One difference between the present study and that of Kesler et al. (1987) is that all females in this study were administered norgestomet before GnRH treatment. Troxel and Kesler (1984b) demonstrated that the administration of norgestomet before GnRH treatment enhanced the duration of the induced LH surge. Therefore, after norgestomet treatment the method of GnRH

administration may be less important on ovulation and corpus luteum formation than in females not norgestomet treated. Prolonging the GnRH-induced preovulatory LH surge without norgestomet treatment enhanced luteal function in previously anestrous ewes (Vincent et al., 1984).

Although it has been well established that short luteal phases frequently (approximately 85% of first ovulations) occur in postpartum females (Garverick et al., 1992 for review), luteal phases can be prolonged by intrauterine indomethacin (a potent inhibitor of prostaglandin synthesis) treatment (Troxel and Kesler, 1984a), hysterectomy (Copelin et al., 1987), and immunization against PGF_{2α} (Copelin et al., 1989). Troxel and Kesler (1984b) further demonstrated that norgestomet treatment before the formation of an anticipated short luteal phase prolonged the luteal phase and reduced prostaglandin metabolite concentrations.

Kesler and Favero (1996) reported a 9% incidence of short luteal phases after Syncro-Mate B treatment. Beal et al. (1984) reported a 7% incidence of shorten estrous cycles after synchronization with norgestomet and alfaprostol, and this study reported a 8% and 2% incidence of short luteal phases in females without and with estrous cycles. Although norgestomet treatment did not eliminate short luteal phases, these data support the conclusions of Troxel and Kesler (1984b) that norgestomet pretreatment effectively reduced the incidence.

Data from this study does not demonstrate why pregnancy rates were higher in females administered GnRH but they generally agree with Troxel et al. (1993) and Hoffman et al. (1995). Overall, the increased ovulation rate may account for 37% and 21% of the increased calving rate for females without and with estrous cycles, respectively. There are no data to explain the effect of GnRH on increasing calving rate, but it may be that GnRH induced a more appropriately timed preovulatory LH surge and ovulation for fertilization from the timed AI.

Alternative methods of estrus synchronization involve the administration of norgestomet (King et al., 1988) or melengestrol acetate (MGA; Brown et al., 1988; Plugge et al., 1990; Jaeger et al., 1992; Yelich et al., 1995; Patterson et al., 1995; Kesler et al., 1996) for 14 d followed by a PGF_{2α} 15 to 17 d later. This procedure has been demonstrated to be very effective in synchronizing estrus and establishing pregnancy in females bred by estrus detection. Although GnRH has not been used with this procedure, it may have value particularly if breeding at a predetermined time is desired.

IMPLICATIONS

Administering GnRH 30 h after norgestomet implant removal may increase synchronized ovulations and calving rate in beef cows and heifers. Although additional animal handling is required, use of GnRH permits breeding at a predetermined time. Since method of GnRH administration after synchronizing with norgestomet had no effect on synchronizing ovulations, corpus luteum function, and calving rate, commercial injectable products may be effective.

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REFERENCES

- Beal, W. E., G. A. Good, and L. A. Peterson. 1984. Estrus synchronization and pregnancy rates in cyclic and noncyclic beef cows and heifers treated with Syncro-Mate B or norgestomet and alfaprostol. *Theriogenology* 22:59.
- Brown, L. N., K. G. Odde, M. E. King, D. E. LeFever, and C. J. Neubauer. 1988. Comparison of MGA-PGF $_{2\alpha}$ to Syncro-Mate B for estrous synchronization in beef heifers. *Theriogenology* 30:1.
- Carmer, S. G., and M. R. Swanson. 1973. An evaluation of ten pair-wise multiple comparison procedures by Monte Carlo methods. *J. Am. Stat. Assoc.* 18:66.
- Chenault, J. R., D. D. Kratzer, R. A. Rzepkowski, and M. C. Goodwin. 1990. LH and FSH response of Holstein heifers to fertirelin acetate, gonadorelin and buserelin. *Theriogenology* 34:81.
- Copelin, J. P., M. F. Smith, H. A. Garverick, and R. S. Youngquist. 1987. Effect of the uterus on subnormal luteal function in anestrous beef cows. *J. Anim. Sci.* 64:1506.
- Copelin, J. P., M. F. Smith, D. H. Keisler, and H. A. Garverick. 1989. Effect of active immunization of pre-partum and post-partum cows against prostaglandin $F_{2\alpha}$ on lifespan and progesterone secretion of short-lived corpora lutea. *J. Reprod. Fertil.* 87:199.
- Garverick, H. A., W. G. Zollers, Jr., and M. F. Smith. 1992. Mechanisms associated with corpus luteum lifespan in animals having normal or subnormal luteal function. *Anim. Reprod. Sci* 28:111.
- Heersche, G., G. H. Kiracofe, R. C. DeBenedetti, S. Wen, and R. M. McKee. 1979. Synchronization of estrus in beef heifers with a norgestomet implant and prostaglandin $F_{2\alpha}$. *Theriogenology* 11:197.
- Helmer, S. D. and J. H. Britt. 1987. Hormone secretion and characteristics of estrous cycles after treatment of heifers with human chorionic gonadotropin or prostaglandin $F_{2\alpha}$ during corpus luteum formation. *J. Anim. Sci.* 64:782.
- Hicks, C. R. 1964. *Fundamental Concepts in the Design of Experiments*. Holt, Rinehart, and Winston, New York.

- Hoffman, D. P., J. S. Stevenson, R. M. McKee, D. A. Nichols, and C. L. Krehbiel. 1995. Pregnancy rates in virgin heifers and suckled beef cows after synchronized ovulation using PGF_{2α}, norgestomet, and GnRH. *J. Anim. Sci.* 73(Suppl. 1):89.
- Jaeger, J. R., J. C. Whittier, L. R. Corah, J. C. Meiske, K. C. Olson, and D. J. Patterson. 1992. Reproductive response of yearling beef heifers to a melengestrol acetate-prostaglandin F_{2α} estrus synchronization system. *J. Anim. Sci.* 70:2622.
- Jochle, W., D. Kuzmanov, and J. Vujosevic. 1982. Estrous cycle synchronization in dairy heifers with the prostaglandin analog alfaprostol. *Theriogenology* 18:215.
- Kesler, D. J. and D. L. Vincent. 1980. Effect of carrier and administration on luteinizing hormone release by gonadotropin releasing hormone. *J. Dairy Sci.* 63:2121.
- Kesler, D. J., H. Khazali, and R. J. Favero. 1990. Quantification of steroids via a polymer linked second antibody enzyme immunoassay system: methods of linking anti-rabbit IgG to poly(styrene). In: C. G. Gebelein and R. L. Dunn (eds.), *Progress in Biomedical Polymers*, Plenum Press, NY.
- Kesler, D. J., P. G. Weston, C. A. Pimentel, T. R. Troxel, D. L. Vincent, and J. E. Hixon. 1981. Diminution of the *in vitro* response to luteinizing hormone by corpora lutea induced by gonadotropin releasing hormone treatment of postpartum suckled beef cows. *J. Anim. Sci.* 53:749.
- Kesler, D. J., L. C. Cruz, E. R. Valle, and T. R. Troxel. 1987. GnRH treatment for infertility: the importance of the delivery profile of preovulatory gonadotropins to the ovary. *Proc. 14th Int. Symp. Cont. Rel. Bioactive Mat.*, p. 85.
- Kesler, D. J. and R. J. Favero. 1995. Estrus synchronization in beef females with norgestomet and estradiol valerate. Part 1: mechanism of action. *Agri-Practice* 16:6.
- Kesler, D. J. and R. J. Favero. 1996. Estrus synchronization in beef females with norgestomet and estradiol valerate. Part 2: factors limiting and enhancing efficacy. *Agri-Practice* 17:12.
- Kesler, D. J., D. B. Faulkner, R. B. Shirley, T. S. Dyson, F. A. Ireland, T. G. Nash, and R. S. Ott. 1996. Effect of interval from melengestrol acetate to prostaglandin F_{2α} on timed and synchronized pregnancy rates of beef heifers and cows. *J. Anim. Sci.* (In Press).
- King, M. E., M. D. Holland, H. S. Mauck, D. G. LeFever, and K. G. Odde. 1988. Synchronization of estrus in beef cows with norgestomet-alfaprostol or Syncro-Mate B. *Theriogenology* 30:785.
- Kiracofe, G. H., L. E. Keay, and K. G. Odde. 1985. Synchronization of estrus in cyclic beef heifers with the prostaglandin analog alfaprostol. *Theriogenology* 24:737.

- Lishman, A. W., S. M. J. Allison, R. L. Fogwell, R. L. Butcher, and E. K. Inskeep. 1979. Follicular development and function of induced corpora lutea in underfed postpartum anestrous beef cows. *J. Anim. Sci.* 48:867.
- Maffeo, G., R. Ballabio, V. Olgiati, and F. Guidobono. 1983. Induction of estrus in cows by a new analogue of PGF_{2α} (alfaprostol). *Prostaglandins* 25:541.
- Odde, K. G. 1990. A review of synchronization of estrus in postpartum cattle. *J. Anim. Sci.* 68:817.
- Patterson, D. J., J. B. Hall, N. W. Bradley, K. K. Schillo, B. L. Woods, and J. M. Kearnan. 1995. Improved synchrony, conception rate, and fecundity in postpartum suckled beef cows fed melengestrol acetate prior to prostaglandin F_{2α}. *J. Anim. Sci.* 73:954.
- Plugge, B. L., G. H. Deutscher, and M. K. Nielson. 1990. Melengestrol acetate (MGA) and prostaglandin F_{2α} program compared to Syncro-Mate B (SMB) for estrous synchronization utilizing AI or natural service. *Prof. Anim. Sci.* 6:29.
- Ramirez-Godinez, J. A., G. H. Kiracofe, R. R. Schalles, and A. B. Moore. 1982. Endocrine patterns in postpartum beef cows associated with weaning. A comparison of the short and subsequent normal cycles. *J. Anim. Sci.* 55:153.
- Steel, R. G. D. and J. H. Torrie. 1980. Principles and procedures of statistics. A biometrical approach. McGraw-Hill Book Co., New York.
- Troxel, T. R., G. F. Cmarik, R. S. Ott, T. F. Lock, and D. J. Kesler. 1983. The effect of method of GnRH administration and short-term calf removal on ovarian function and reproductive performance in postpartum suckled beef cows administered PGF_{2α} for estrous synchronization. *Theriogenology* 20:417.
- Troxel, T. R. and D. J. Kesler. 1984a. Ability of indomethacin to alter prostaglandin metabolite concentrations and to enhance the function of corpora lutea induced in postpartum suckled beef cows. *J. Anim. Sci.* 59:177.
- Troxel, T. R. and D. J. Kesler. 1984b. The effect of progestin and GnRH treatments on ovarian function and reproductive hormone secretions of anestrous postpartum suckled beef cows. *Theriogenology* 21:699.
- Troxel, T. R., L. C. Cruz, R. S. Ott, and D. J. Kesler. 1993. Norgestomet and gonadotropin-releasing hormone enhance corpus luteum function and fertility of postpartum suckled beef cows. *J. Anim. Sci.* 71:2579.
- Vincent, D. L. and D. J. Kesler. 1985. Prolonged release of gonadotropin releasing hormone enhanced subsequent pituitary and ovarian responses of postpartum anestrous ewes. *Proc. 12th Int. Symp. Cont. Rel. Bioactive Mat.*, pp. 247.

- Vincent, D. L., A. R. Kinser, and D. J. Kesler. 1984. The effect of method of administration on ovarian response of seasonally anestrous ewes administered gonadotrophin releasing hormone. *Anim. Reprod. Sci.* 6:267.
- Whittier, J. C., G. H. Deutscher, and D. C. Clanton. 1986. Progestin and prostaglandin for estrous synchronization in beef heifers. *J. Anim. Sci.* 63:700.
- Wiseman, B. S., D. L. Vincent, P. J. Thomford, N. S. Scheffrahn, G. F. Sargent, and D. J. Kesler. 1983. Changes in porcine, ovine, bovine, and equine blood progesterone concentrations between collection and centrifugation. *Anim. Reprod. Sci.* 5:161.
- Yelich, J. V., H. S. Mauck, M. D. Holland, and K. G. Odde. 1995. Synchronization of estrus in suckled postpartum beef cows with melengestrol acetate and $\text{PGF}_{2\alpha}$. *Theriogenology* 43:389.
- Zelinski-Wooten, M. B., S. E. Lanzendorf, D. P. Wolf, Y. A. Chandrasekher, and R. L. Stouffer. 1991. Titrating luteinizing hormone surge requirements for ovulatory changes in primate follicles. I. Oocyte maturation and corpus luteum function. *J. Clin. Endocrinol. Metab.* 73:577.

Table 1. Ovulation rates of beef females administered GnRH after norgestomet and prostaglandin F_{2α} estrus synchronization.^a

GnRH	-Estrous Cycles ^b -		Combined
	-	+	
None	78/ 98 (80)	76/ 84 (91)	154/182 ^y (85)
Injected ^c	79/ 81 (98)	87/ 90 (97)	166/171 ^z (97)
Implanted ^d	81/ 87 (93)	91/ 93 (98)	172/180 ^z (96)
Combined	238/266 ^x (90)	254/267 ^y (95)	

^aFemales were implanted with norgestomet implants that were left in situ for 8 d. Approximately 28 h before implant removal females were administered PGF_{2α}.

Approximately 30 h after implant removal, females that received GnRH were treated. All females were bred via AI approximately 48 h after implant removal.

^bFemales were considered to be with (+) or without (-) estrous cycles based on 3 (d - 11 and at norgestomet implantation, and at PGF_{2α} treatment) blood progesterone concentrations before PGF_{2α} treatment.

^cGnRH was dissolved in a potassium phosphate buffer and administered intramuscularly in the rear leg musculature.

^dLyophilized GnRH in gelatin capsules was subcutaneously administered behind the shoulder.

^{x,y}Values with different superscripts within a row differ (P < .05).

^{y,z}Values with different superscripts within a column differ (P < .01).

Table 2. The incidence of short estrous cycles in beef females administered GnRH after norgestomet and prostaglandin F_{2α} estrus synchronization.^a

GnRH	-Estrous Cycles ^b -		Combined
	-	+	
None	5/ 78 (6)	2/ 76 (3)	7/154 (5)
Injected ^c	7/ 79 (9)	1/ 87 (1)	8/166 (5)
Implanted ^d	8/ 81 (10)	3/ 91 (3)	11/172 (6)
Combined	20/238 ^y (8)	6/254 ^z (2)	

^aFemales were implanted with norgestomet implants that were left in situ for 8 d. Approximately 28 h before implant removal females were administered PGF_{2α}. Approximately 30 h after implant removal, females that received GnRH were treated. All females were bred via AI approximately 48 h after implant removal.

^bFemales were considered to be with (+) or without (-) estrous cycles based on 3 (d - 11 and at norgestomet implantation, and at PGF_{2α} treatment) blood progesterone concentrations before PGF_{2α} treatment.

^cGnRH was dissolved in a potassium phosphate buffer and administered intramuscularly in the rear leg musculature.

^dLyophilized GnRH in gelatin capsules was subcutaneously administered behind the shoulder.

^{y,z}Values within a row with different superscripts differ (P < .01).

Table 3. Calving rates of beef females administered GnRH after norgestomet and prostaglandin F_{2α} estrus synchronization.^a

GnRH	-Estrous Cycles ^b -		Combined
	-	+	
None	23/ 98 (23)	33/ 84 (39)	56/182 ^x (31)
Injected ^c	28/ 81 (35)	47/ 90 (52)	75/171 ^y (44)
Implanted ^d	28/ 87 (32)	48/ 93 (52)	76/180 ^y (42)
Combined	79/266 ^y (30)	128/267 ^z (48)	

^aFemales were implanted with norgestomet implants that were left in situ for 8 d. Approximately 28 h before implant removal females were administered PGF_{2α}. Approximately 30 h after implant removal, females that received GnRH were treated. All females were bred via AI approximately 48 h after implant removal.

^bFemales were considered to be with (+) or without (-) estrous cycles based on 3 (d - 11 and at norgestomet implantation, and at PGF_{2α} treatment) blood progesterone concentrations before PGF_{2α} treatment.

^cGnRH was dissolved in a potassium phosphate buffer and administered intramuscularly in the rear leg musculature.

^dLyophilized GnRH in gelatin capsules was subcutaneously administered behind the shoulder.

^{x,y}Values with different superscripts within a column differ (P < .05).

^{y,z}Values with different superscripts within a row differ (P < .01).

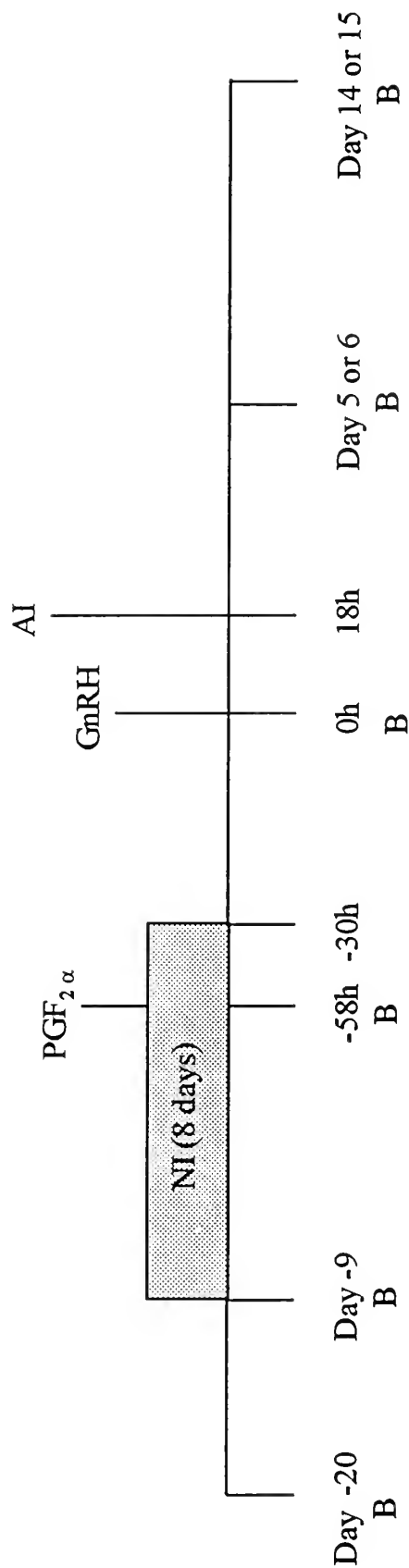


Figure 1. Treatment and blood collection schedule. The B represents the time of blood collection. Blood samples were assayed for progesterone concentrations. At the time of GnRH, females were randomly assigned to one of three groups: no GnRH, GnRH intramuscularly in saline, and GnRH implanted subcutaneously in gelatin capsules.

NEEDLE-LESS IMPLANT DELIVERY OF GONADOTROPIN RELEASING HORMONE ENHANCES THE CALVING RATE OF BEEF COWS SYNCHRONIZED WITH NORGESTOMET AND ESTRADIOL VALERATE

D. J. Kesler and R. J. Favero

SUMMARY

One-hundred and six beef cows were included in a study to determine if gonadotropin releasing hormone (GnRH) administered via needle-less implants would enhance calving rate as conventional GnRH administration. All cows were synchronized with the norgestomet and estradiol valerate estrus synchronization procedure and then randomly assigned to one of three groups: no GnRH, GnRH via conventional implants, and GnRH via needle-less implants. GnRH was administered 30 hours after norgestomet implant removal. Although needle-less implants were administered while cows were restrained, they may be administered remotely. GnRH administered by both methods equally enhanced ($P < .05$) calving rate and the needle-less implant caused minimal response by the cows. Therefore, remote administration of GnRH may accomplish therapeutic efficacy and reduce the time, labor, stress, and risk of injury associated with providing conventional animal therapy.

INTRODUCTION

Although several estrus synchronization procedures have been developed, most require that the synchronized females be bred over several days at estrus (12). The only procedure that enables artificial insemination (AI) at a single predetermined time utilizes a norgestomet implant and an injection of a luteolytic or an anti-luteotropin compound (9, 12). Pregnancy rates of cattle synchronized with these types of products, however, have been variable because of asynchronized ovulations and short luteal phases (10).

It was previously demonstrated that the administration of gonadotropin releasing hormone (GnRH) 30 hours after norgestomet implant removal enhanced timed AI pregnancy rates (6, 13, 14). Use of GnRH at this time, however, requires additional chute processing and animal handling. In addition to requiring significant time, processing the cows also causes stress and increases the chance of injury (11) and stress during the interval between implant removal and estrus has been demonstrated to decrease fertility (5, 10).

Because it would be highly advantageous to administer GnRH without chute processing, a new method of remote drug delivery was evaluated. The objective of this experiment was to determine if GnRH administered 30 hours after norgestomet implant removal via the remote drug delivery system would effectively enhance calving rate as GnRH administered via conventional implants.

MATERIALS AND METHODS

One-hundred and six cross-bred beef cows suckling calves were used. All cows were administered Syncro-Mate B® (SMB; Rhone Merieux, Inc.). The SMB procedure consists of an intramuscular injection of norgestomet (3.0 mg) and estradiol valerate (5.0 mg) in sesame oil and benzyl alcohol and a hydron implant that contained 6.0 mg of norgestomet (9). The implant was subcutaneously implanted on the convex surface of the ear. At the end of 9 days the norgestomet implants were removed and cows were randomly assigned to one of three groups. Cows assigned to group 1 ($n = 38$) received no further treatments. Cows assigned to groups 2 ($n = 33$) and 3 ($n = 35$) were administered 250 μg of GnRH 30 hours after norgestomet implant removal. Although the GnRH formulation was the same for implants administered to cows in groups 2 and 3, the method of administration differed. The cows in group 2 were processed in a chute and administered the GnRH via an subcutaneous ear implant. For group 3, the GnRH formulation was placed in a needle-less implant and administered intramuscularly via a compressed air delivery system (11) while cows were in the chute. After administration of the needle-less implants, the penetration sites were inspected to insure administration. Approximately 48 hours after norgestomet implant removal all cows were inseminated by a single inseminator. The semen was from multiple bulls of known fertility. Service sire selection was made before the timed AI and before the cows were randomly allotted to treatment groups. Five days after AI all cows were exposed to bulls for the remainder of the 63 day breeding season. Calving rates were based on calving dates the following spring. Chi-square analysis was used to determined difference among groups (1).

RESULTS AND DISCUSSION

GnRH, regardless of method of administration, enhanced calving rate ($P < .05$; Table 1). Calving rate of the cows administered GnRH via conventional implantation (61%) was not different ($P > .10$) from calving rate (60%) of cows administered GnRH via needle-less implantation (Table 1). This improvement in calving rate was similar to previous reports and has been observed in all studies conducted, regardless of method of GnRH administration (Table 2). The increase in calving rate was greater in the studies with lower calving rates in the non-GnRH treated females (Table 2).

The needle-less implant penetrated the skin in all the treated cows. A slit, smaller than the diameter of the implant, and a few drops of blood were present after administration. One of three behavioral reactions was displayed by the cows upon treatment. Some of the cows reacted with a kick, others turned their head to look curiously, and others had no reaction as they appeared more concerned by the restraint. Kesler et al. (11) monitored cortisol concentrations in heifers treated similarly and reported that the small elevation observed was similar to the cortisol response after intramuscular injection. Deer treated remotely, however, had no elevation in cortisol concentrations (11).

Although a remote delivery system was used, since this was the first use of this system in cows, it was used while in the cows were restrained in order to insure penetration. Therefore, advantages of remote delivery were not realized. However, these data demonstrate that the needle-less implant is efficacious in delivering GnRH for this therapeutic condition. Therefore,

the benefits of GnRH 30 hours after norgestomet implant removal could be realized with significantly less effort and risk. There are several ways in which this system could be implemented. One method is to move cattle slowly down a narrow passage and treat them as they pass. Alternatively, after providing feed to the cattle, one may walk behind them treating the cows as they are consuming their feed.

As reported in Table 2 the stress of venipuncture and transport at the time of GnRH treatment decreased calving rate. Therefore, some of the improvement observed in calving rate may be due to overcoming handling induced stress as the decreased calving rate caused by stress is due to a suppression of the preovulatory luteinizing hormone surge. However, the calving rate (50%) summarized in the studies using GnRH 30 hours after norgestomet implant removal is higher than the calving rate (40%) summarized by Kesler and Favero (10) of 1202 non-GnRH treated females.

The needle-less implants have also been successfully used for other therapeutic conditions in deer (2, 3, 4, 7), cattle (8), goats (11), and horses (15). Because of the benefits associated with administering compounds via remote delivery of needle-less implants, this system may have many practical uses in domestic and wild animals.

REFERENCES

- W. G. Cochran and G. M. Cox, *Experimental Designs* (2nd ed.). John Wiley & Sons, New York, 1957.
- A. J. DeNicola, R. K. Swihart, and D. J. Kesler, The effect of remotely delivered gonadotropin formulations on reproductive function of white-tailed deer. *Drug Dev. Ind. Pharm.* (In Press).
- A. J. DeNicola, D. J. Kesler, and R. K. Swihart, Dose determination and efficacy of remotely delivered norgestomet implants on contraception of white-tailed deer, *Zoo Biol.* (In Press).
- A. J. DeNicola, D. J. Kesler, and R. K. Swihart, Remotely delivered prostaglandin $F_{2\alpha}$ implants terminate pregnancy in white-tailed deer, *J. Wildl. Manage.* (Submitted).
- D. L. Hixon, D. J. Kesler, T. R. Troxel, D. L. Vincent, and B. S. Wiseman, Reproductive hormone secretions and first service conception rate subsequent to ovulation control with Syncro-Mate B, *Theriogenology*, 16, 219 (1981).
- D. P. Hoffman, J. S. Stevenson, R. M. McKee, D. A. Nichols, and C. L. Krehbiel, Pregnancy rates in virgin heifers and suckled beef cows after synchronized ovulation using $PGF_{2\alpha}$, norgestomet, and GnRH, *J. Anim. Sci.* 73, (Suppl. 1), 89 (1995).
- N. K. Jacobsen, D. A. Jessup, and D. J. Kesler, Contraception of captive black-tailed deer by remotely delivered norgestomet ballistic implants, *Wildl. Soc. Bull.*, 23, 718 (1995).

- D. J. Kesler and R. J. Favero, Estrous synchronization and fertility enhancement in cattle with ballistically administered pharmaceutical agents, *Proc. Int. Symp. Cont. Rel. Bioactive Mat.*, 12, 247 (1989).
- D. J. Kesler and R. J. Favero, Estrus synchronization in beef females with norgestomet and estradiol valerate. Part 1: mechanism of action, *Agri-Practice* 16, 6 (1995).
- D. J. Kesler and R. J. Favero, Estrus synchronization in beef females with norgestomet and estradiol valerate. Part 2: factors limiting and enhancing efficacy, *Agri-Practice* 17, 12 (1996).
- D. J. Kesler, D. T. Bechtol, and A. J. DeNicola, A new method of administering pharmaceuticals and vaccines to animals: remote delivery in biodegradable, needle-less implants, *J. Am. Vet. Med. Assoc.* (Submitted).
- K. G. Odde, A review of synchronization of estrus in postpartum cattle, *J. Anim. Sci.* 68, 817 (1990).
- T. R. Troxel, L. C. Cruz, R. S. Ott, and D. J. Kesler, Norgestomet and gonadotropin-releasing hormone enhance corpus luteum function and fertility of postpartum suckled beef cows, *J. Anim. Sci.* 71, 2579 (1993).
- E. R. Valle, L. C. Cruz, R. S. Ott, and D. J. Kesler, Gonadotropin releasing hormone enhances the calving rate of beef females administered norgestomet and prostaglandin $F_{2\alpha}$ for estrus synchronization, *J. Anim. Sci.* (Submitted).
- P. Willis, G. L. Heusner, R. J. Warren, D. Kesler, and R. A. Fayrer-Hosken, Equine immunocontraception using porcine zona pellucida: a new method for remote delivery and characterization of the immune response, *J. Equine Vet. Sci.*, 14, 364 (1994).

Table 1. The effect of gonadotropin releasing hormone^a administered via needle-less implants on the calving rate of postpartum beef cows synchronized with norgestomet and estradiol valerate^b.

Treatment Group	Calving Rate
Control	14/38 (37%) ^x
GnRH-Conventional implant	20/33 (61%) ^y
GnRH-Needle-less implant	21/35 (60%) ^y

^aGonadotropin releasing hormone was administered 30 hours after norgestomet implant removal.

^bEach cow was administered a norgestomet implant for 9 days. At the time of implantation each cow also received an intramuscular injection of 5 mg estradiol valerate and 3 mg norgestomet (Syncro-Mate B®).

^{x,y}Values with different superscripts differ ($P < .05$).

Table 2. Summary of pregnancy rates of stressed females and females administered GnRH 30 hours after norgestomet implant removal.

Study	Control	Stress/ GnRH	Diminution/ Enhancement
Stressed:			
Hixon et al. (5) venipuncture	19/ 48 (40%)	8/ 38 (21%)	- 48%
Kesler & Favero (10) transport	6/ 10 (60%)	2/ 12 (17%)	- 72%
GnRH treated:			
Troxel et al. (13) implanted	9/ 33 (27%)	19/ 32 (59%)	+ 119%
injected	18/100 (18%)	34/ 74 (46%)	+ 156%
Hoffmann et al. (6) injected	50/104 (48%)	69/106 (65%)	+ 35%
Valle et al. (14) injected	56/182 (31%) ^a	75/171 (44%)	+ 42%
implanted	56/182 (31%) ^a	76/180 (42%)	+ 36%
Present Study implanted	14/ 38 (37%) ^b	20/ 33 (61%)	+ 65%
needle-less	14/ 38 (34%) ^b	21/ 35 (60%)	+ 62%
Combined	147/457 (32%)	314/631 (50%)	

^aSame data repeated for illustrations purposes.

^bSame data repeated for illustrations purposes.

EFFECT OF A SUSTAINED RELEASE INJECTION OF HUMAN CHORIONIC GONADOTROPIN ON CORPUS LUTEUM FORMATION AND PROGESTERONE SECRETION IN BEEF HEIFERS

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SUMMARY

A sustained release injection of human chorionic gonadotropin (HCG) was administered to Syncro-Mate B® synchronized heifers 12 hours after estrus. The sustained release formulation doubled the ovulation rate, increased corpora lutea size, increased the incidence of cystic corpora lutea, and tended to increase progesterone concentrations. Sustained release of HCG produced effects similar to larger doses and/or multiple aqueous injections of HCG. The doubling of multiple ovulations may have been a result of availability of persistent follicles caused by the Syncro-Mate B®. The increase in corpora lutea size was partially caused by the more frequent presence of fluid filled cavities within the corpora lutea (cystic corpora lutea). In summary, the sustained release injection of HCG appeared to accomplish similar effects as larger doses and/or multiple administrations of non-sustained release formulations of HCG.

INTRODUCTION

There have been several publications demonstrating that the administration of human chorionic gonadotropin (HCG) during met-estrus increases corpora lutea size, progesterone synthesis, and fertility (4, 23, 24). The enhancement of fertility, however, has not been observed in all studies conducted (8, 9, 16). In order to obtain an optimal effect, large doses of HCG have been administered over several days. These factors (large quantities of HCG and multiple administration times) decrease the likelihood of commercial use of HCG for fertility enhancement.

In addition to enhancement of fertility, the increased progesterone concentrations post-treatment may increase fertility at a subsequent estrus (9). Data demonstrate that progesterone secretion during the estrous cycle proceeding insemination was greater in cows that conceived than those that did not conceive (6, 7). Therefore, the advantages of HCG administration during met-estrus may be two fold. However, the therapy must be capable of being implemented at one convenient time in order for the procedure to be realized commercially.

The objective of this study was to determine the effectiveness of a single sustained injection of HCG administered at the time of insemination, when cows are already restrained, on increasing corpus luteum size and progesterone secretion.

MATERIALS AND METHODS

Thirty crossbred beef heifers managed on dry lot at the University of Illinois Beef Unit were included in this study. Heifers were selected for the study from a larger group based on being in good body condition and being detected in estrus the month before initiating the study. All heifers were administered Syncro-Mate B® (Rhone Merieux, Inc, Athens, GA). Syncro-Mate B® consists

of administering a hydron ear implant containing 6 mg norgestomet. The implant is subcutaneously implanted on the convex surface of the ear. At the same time, treated females are administered a 2 ml intramuscular injection containing 3.0 mg norgestomet and 5.0 mg estradiol valerate in sesame oil. Implants are removed nine days after implantation and treated females are expected to be in estrus 24 to 48 hours after implant removal.

Approximately 12 hours after the first detection of estrus, one-half (15) of the heifers were administered a sustained release injection (2 ml) of human chorionic gonadotropin (HCG). Each ml of the injection contained 750 I.U. of HCG. Therefore, HCG treated heifers received a total dose of 1500 I.U. of HCG. Other components of the sustained release injection were lactose, wax, methylparaben, and propylparaben, in sesame oil and was demonstrated to release the HCG over a three day period (unpublished data). The other one-half of the heifers received no treatment at the time of HCG treatment and served as controls. All heifers were detected in estrus and all HCG injections were administered two days after Syncro-Mate B implant removal.

Six days after the time of the HCG treatment, heifers were bled and serum harvested and frozen. Ten days after the time of HCG treatment all heifers were again bled (and serum harvested and frozen) and all ovariectomized by a sterile surgical procedure through the flank (13). Ovaries were examined and follicular number and size (surface diameter), corpora lutea number and size (weight), and number of cystic corpora lutea (corpora lutea with cavities) recorded. Immediately after surgical removal of the ovaries, heifers were administered a therapeutic dose of an antimicrobial (Liquamycin® LA 200®; Pfizer, Inc., Animal Health, New York, NY).

Blood serum was assayed for progesterone concentrations by a validated enzyme immunoassay (12). All qualitative data were analyzed by Chi-square analysis (21) and quantitative data were analyzed by nested analysis of variance (10).

RESULTS

Twenty-seven (27) of the heifers had corpora lutea indicating that they had ovulated subsequent to the synchronized estrus. For those that did not ovulate, one was a control heifer and two were HCG treated heifers. For the heifers that ovulated, 9 had multiple corpora lutea. Although not significant ($P > .15$), twice as many HCG treated heifers had multiple ovulations as control heifers (Table 1). All but one heifer with multiple corpora lutea had two corpora lutea. The one exception had 4 corpora lutea.

Mean corpora lutea weights are reported in Table 1. Corpora lutea of HCG treated heifers with multiple corpora lutea were heavier ($P < .01$) than corpora lutea of control heifers. Although heavier, the variation in corpora lutea weights was greater ($P < .05$) for HCG treated heifers than for control heifers. Progesterone concentrations tended to be higher ($P = .075$) for HCG treated heifers with a single corpus luteum than for control heifers with a single corpus luteum on both days 6 and 10.

As reported in Table 2, HCG treated heifers tended to have fewer ($P = .07$) medium size follicles than control heifers and more ($P < .01$) of the corpora lutea from HCG treated heifers than control heifers were cystic.

On day 6, all heifers that had corpora lutea had progesterone concentrations greater than 1.0 ng/ml. For the heifers that did not ovulate, progesterone concentrations in the control heifer were less than .5 ng/ml whereas the HCG treated heifers had mean progesterone concentrations of 1.34 ng/ml. Examination of the follicles of these two HCG treated heifers revealed luteinization of the follicular wall which may have been the source of the progesterone (3,5).

Blood progesterone concentrations on day 10 (day of ovariectomy) were not correlated ($r = .12$; $P > .15$) with corpora lutea weight. In fact, HCG treated heifers with corpora lutea two standard deviations or greater than the mean of the control heifers (mean 6.77 g; $n = 6$) had progesterone concentrations (5.6 ng/ml) similar ($P > .15$) to progesterone concentrations (6.5 ng/ml) in HCG treated heifers that had corpora lutea of similar size to the control heifers (mean = 3.6 g; $n = 7$).

DISCUSSION

This study demonstrates that a single injection of HCG, in a sustained release format, enhanced the development of corpora lutea and increased progesterone secretion by the corpora lutea in a similar magnitude to multiple injections. The sustained release injection used in our study increased corpora lutea weight by about one and one-half times that of a conventional injection at a similar time (12 hours post-estrus; 23). Further, progesterone concentrations were similarly increased with the sustained release injection as 3.33 times the dose of HCG by conventional injection (23).

All heifers were synchronized with Syncro-Mate B® prior to HCG administration for convenience. This may have been the cause of the multiple corpora lutea observed in this study. Although Syncro-Mate B® effectively synchronizes estrus and ovulation in beef females (11, 14, 15, 17), there have been studies reporting the presence of persistent follicles in Syncro-Mate B® treated females (18, 20, 22). Our data supports the presence of persistent follicles by the presence of a high number of multiple corpora lutea in both control and HCG treated heifers. HCG doubled the incidence of multiple corpora lutea, therefore, apparently ovulating persistent follicles that normally don't ovulate. In addition, fewer medium size follicles were observed in the HCG treated heifers. In the two HCG treated heifers that did not ovulate, the follicles were luteinized and were synthesizing progesterone which was not detected in the control heifer that did not ovulate. Gonadotropins have been previously demonstrated to luteinize ovarian follicles (3, 5).

Although, both corpora lutea weights and progesterone concentrations were increased, in contrast to a previous report (1) they appeared to be independently increased based on the lack of a positive correlation between corpora lutea size and progesterone concentrations. This may have been caused by the higher percentage of cystic corpora lutea in the HCG treated heifers. Cystic corpora lutea result from ovulations and maintain pregnancy as effectively as normal corpora lutea (19). However, the presence of the fluid filled cavity in cystic corpora lutea increase their size and weight without increasing the progesterone synthesizing luteal cells.

REFERENCES

- Armstrong, D.T. and D.L. Black. Influence of luteinizing hormone on corpus luteum metabolism and progesterone biosynthesis throughout the bovine estrous cycle. *Endocrinology* 78:937 (1966).
- Anderson, L.H., and M.L. Day. Acute progesterone administration regresses persistent dominant follicles and improves fertility of cattle in which estrus was synchronized with melengestrol acetate. *J. Anim. Sci.* 72:2955 (1994).
- Brown, E.M., R.G. Elmore, H.A. Garverick, and D.J. Kesler. Gonadotropin releasing hormone treatment of dairy cows with ovarian cysts. II. Histology of ovarian cyst walls. *Theriogenology* 17:689 (1982).
- Brown, H., J.F. Wagner, R.P. Rathmacher, J.W. McAskill, N.G. Elliston, and R.F. Bing. Effect of human chorionic gonadotropin on pregnancy rate of heifers when used under field conditions. *J. Am. Vet. Med. Assoc.* 162:456 (1973).
- D'Amato, C., J. Bahr, B. Stockert, F. Calvo, and D. Kesler. Long term perfusion of rabbit ovarian follicles. In: *Ovarian Follicular and Corpus Luteum Function* (C.P. Channing, J.M. Marsh, and W.A. Sadler, eds.), Plenum Publishing Corp., New York, NY (1979).
- Erb, R.E., H.A. Garverick, R.D. Randel, B.L. Brown, and C.J. Callahan. Profiles of reproductive hormones associated with fertile and nonfertile inseminations of dairy cows. *Theriogenology* 5:227 (1976).
- Fonseca, F.A., J.H. Britt, B.T. McDaniel, J.C. Wilk, and A.H. Rakes. Reproductive traits of Holsteins and Jerseys. Effects of age, milk yield, and clinical abnormalities on involution of cervix and uterus, ovulation, estrous cycles, detection of estrus, conception rate, and days open. *J. Dairy Sci.* 66:1128 (1983).
- Hansel, W., R.W. Spalding, L.L. Larson, D.B. Laster, J.F. Wagner, and R.K. Braun. Influence of human chorionic gonadotropin on pregnancy rates in lactating dairy and beef cows. *J. Dairy Sci.* 59:751 (1976).
- Helmer, S.D. and J.H. Britt. Fertility of dairy cattle treated with human chorionic gonadotropin (hCG) to stimulate progesterone secretion. *Theriogenology* 26:683 (1986).
- Hicks, C.R. *Fundamental Concepts in the Design of Experiments.* Holt, Rinehart and Winston, New York, NY (1964).
- Hixon, D. L., D. J. Kesler, T. R. Troxel, D. L. Vincent, and B. S. Wiseman. Reproductive hormone secretions and first service conception rate subsequent to ovulation control with Syncro-Mate B. *Theriogenology* 16:219 (1981).

- Kesler, D. J., H. Khazali, and R. J. Favero. Quantification of steroids via a polymer linked second antibody enzyme immunoassay system: methods of linking anti-rabbit IgG to polystyrene. In: C. G. Gebelien and R. L. Dunn (Ed.) *Progress in Biomedical Polymers*. Plenum Publishing, New York (1990).
- Kesler, D.J., R.G. Elmore, E.M. Brown, and H.A. Garverick. Gonadotropin releasing hormone treatment of dairy cows with ovarian cysts. I. Gross ovarian morphology and endocrinology. *Theriogenology* 16:207 (1982).
- Kesler, D.J. and R.J. Favero. Estrus synchronization in beef females with norgestomet and estradiol valerate. Part 2: factors limiting and enhancing efficacy. *Agri-Practice* 17:12-17 (1996).
- Kesler, D.J., R.J. Favero, and T.R. Troxel. A comparison of hydron and silicone implants in the bovine norgestomet and estradiol valerate estrus synchronization procedure. *Drug Development and Industrial Pharmacy* 21:475 (1995).
- Morris, L.M., E. Gonzalez-Padilla, G.D. Niswender, and J.N. Wiltbank. Peripheral progesterone levels in pregnant and not-pregnant heifers following use of HCG. *Theriogenology* 6:367 (1976).
- Odde, K. G. A review of synchronization of estrus in postpartum cattle. *J. Anim. Sci.* 68:817 (1990).
- Rajamahendran, R., and C. Taylor. Follicular dynamics and temporal relationships among body temperature, oestrus, the surge of luteinizing hormone and ovulation in Holstein heifers treated with norgestomet. *J. Reprod. Fertil.* 92:461 (1991).
- Roberts, S.J. *Veterinary Obstetrics and Genital Diseases*. Edwards Brothers, Inc., Ann Arbor, MI (1971).
- Savio, J.D., W.W. Thatcher, L. Badinga, R.L. de la Sota, and D. Wolfenson. 1993. Regulation of dominant follicle turnover during the oestrous cycle in cows. *J. Reprod. Fertil.* 97:197 (1993).
- Steel, R.G.D. and J.H. Torrie. *Principles and Procedures of Statistics: A Biometrical Approach*. McGraw-Hill Book Co., New York, NY (1980).
- Stock, A.E., and J. E. Fortune. Ovarian follicular dominance in cattle: relationship between prolonged growth of the ovulatory follicle and endocrine parameters. *Endocrinology* 132(3):1108 (1993).
- Veenhuizen, E.L., J.F. Wagner, and L.V. Tonkinson. Corpus luteum response to 6-chloro Δ^6 -17 acetoxypregesterone and HCG in the cow. *Biol. Reprod.* 6:270 (1972).

Wagner, J.F., E.L. Veenhuizen, L.V. Tonkinson, and R.P. Rathmacher. Effect of placental gonadotropin on pregnancy rate in the bovine. J. Anim. Sci. 36:1129 (1973).

Table 1. Number and weight of corpora lutea and serum concentrations of progesterone on days 6 and 10 after the time of HCG treatment.

	Control		HCG	
	Single	Multiple	Single	Multiple
Number ^a	11 (73%)	3 (20%)	7 (47%)	6 (40%)
Weight:				
Mean	2.98 g	1.47 g	4.10 g	3.09 g ^b
Variance	.52	.23	3.94 ^c	2.20 ^c
Progesterone ^d :				
day 6	2.31	2.06	3.50 ^e	2.83
day 10	4.00	3.38	6.23 ^e	5.87

^aThere were 15 heifers per group. One control heifer and two HCG treated heifer did not ovulate and no corpora lutea were present.

^bCorpora lutea of HCG treated heifers had more ($P < .01$) mass than control heifers.

^cVariance associate with corpora lutea weights was greater ($P < .05$) for HCG treated heifers than for control heifers.

^dProgesterone concentrations (ng/ml) in the serum.

^eThere tended ($P = .075$) to be more progesterone secreted by HCG treated heifer than for control heifers.

Table 2. Incidence of follicles and corpora lutea cavities in heifers 10 days after the time of HCG treatment and progesterone concentrations on days 6 and 10.

	Control	HCG
Follicles:		
0.5 - 1.5 cm	2.1	0.9 ^a
> 1.5 cm	0.2	0.8
Cystic corpora lutea	15.8 %	57.9 % ^b
Progesterone: ^c		
day 6	2.25	3.19
day 10	3.87	6.06 ^d

^aHCG treated heifers tended to have fewer ($P = .07$) .5 to 1.5 cm follicles.

^bHCG treated heifers had more ($P < .01$) corpora lutea with fluid filled cavities (cystic corpora lutea).

^cProgesterone concentrations (ng/ml) in the serum.

^dThere tended ($P = .065$) to be more progesterone secreted by HCG treated heifer than for control heifers.

NORGESTOMET IMPLANTS MAINTAIN PREGNANCY IN OVARIECTOMIZED HEIFERS

D. J. Kesler

SUMMARY

Fifty-five heifers were synchronized with Syncro-Mate B® and artificially inseminated (AI) approximately 48 hours after removal of the norgestomet implants. Ten days after AI, 15 of the heifers were ovariectomized and each ovariectomized heifer was subcutaneously implanted with two 15 mg norgestomet/silicone implants on the convex surface of the ear. The silicone/norgestomet implants were changed every 55 ± 4 days (mean \pm range) thereafter and the last sets of implants were removed 273 days after AI. Sixty-five percent and 53% of the control and ovariectomized/norgestomet implanted heifers were pregnant 44 days after AI ($P > .10$). Pregnancies were lost in two ovariectomized/norgestomet implanted heifers (44 to 96 days after AI) and in one heifer that lost one of the two implants 65 to 96 days after AI. Ninety-six days after AI the implants were removed from two of the pregnant ovariectomized/norgestomet implanted heifers. These two heifers were open at 116 days after AI. All ovariectomized/norgestomet implanted heifers pregnant at 273 days after AI ($n = 3$) calved an average of 41 hours after removal of the last set of norgestomet/silicone implants. Dystocia ($P < .05$), retention of fetal membranes ($P < .01$), and calf mortality ($P < .01$) were higher for the ovariectomized/norgestomet implanted heifers than for the control heifers.

INTRODUCTION

Ovariectomy of pregnant cattle has diverse outcomes that are affected by the stage of gestation when ovariectomized. Cattle ovariectomized early in gestation (< 118 days of gestation) abort without exception and with minimal complications (1, 2). Most cows ovariectomized on days 173 to 237 of gestation do not abort, but the majority calve preterm at variable intervals after ovariectomy and have a higher than normal incidence of retained fetal membranes, dystocia, and calf mortality even if gestation is maintained to near term (1, 3). Progesterone and melengestrol acetate (MGA) have been administered to maintain pregnancy in ovariectomized cattle (2, 4, 5). However, even with the administration of exogenous progestins, although pregnancy is maintained, there is a higher than normal incidence of embryonic mortality, incidence of retained fetal membranes, dystocia, and calf mortality (2).

Syncro-Mate B®, which contains the progestin norgestomet, is approved by the FDA for estrus synchronization in cattle (6). Norgestomet is a modified 19-norprogesterone and has been demonstrated to be a highly biologically active progestin. Gilbert et al. (7) demonstrated that norgestomet is 15 times more biologically active than progesterone when orally administered to rabbits. Gilbert et al. (7) further demonstrated that norgestomet was 216 times more biologically active than progesterone when subcutaneously administered to estradiol-17 β treated mice. Wishart (8) and Machado and Kesler (9) have demonstrated that approximately 140 μ g of norgestomet was needed daily to suppress estrus in cattle vs a minimal daily dosage of 45 mg of progesterone (8).

Although norgestomet has been effectively used to suppress estrus in cattle, it has not been previously used to maintain pregnancy in ovariectomized cattle. The objective of this experiment was to determine if norgestomet would maintain pregnancy in ovariectomized heifers and if pregnancy was maintained, to determine if the events associated with parturition were normal.

MATERIALS AND METHODS

Fifty-five crossbred beef heifers (12 to 15 months of age) that were synchronized with Syncro-Mate B® and artificially inseminated (AI) approximately 48 hours after norgestomet implant removal were used in this study. The heifers were managed at the University of Illinois Beef Unit. The Syncro-Mate B® procedure consisted of an intramuscular injection of norgestomet (3 mg) and estradiol valerate (5 mg) and the implantation of a 6 mg norgestomet implant. The norgestomet implants were placed subcutaneously on the convex surface of the ears and were left in situ for 9 days.

Ten days after AI, fifteen of the heifers were ovariectomized by a sterile surgical procedure through the flank (10). Immediately after surgical removal of the ovaries, heifers were administered a therapeutic dose (2 mg per kg body weight) of an anti-microbial (Liquamycin® LA 200®; 6). Upon removal of the ovaries, the ovaries were examined for extent of ovarian tissue removed and the presence (or absence) of corpora lutea.

At the time of ovariectomy, all ovariectomized heifers were subcutaneously implanted with two matrix type silicone implants that were .45 cm in diameter and 2.0 cm long and manufactured to contain 15 mg of norgestomet each. The implants were subcutaneously implanted on the convex surface of the ear (one in each ear). The two norgestomet implants implanted at ovariectomy were removed 55 days later (65 days after AI) and heifers were implanted with two new implants. Additional implant removal and implant insertion times for the pregnant ovariectomized/norgestomet implanted heifers were on days 116, 175, and 234 after AI. Per rectum examinations of the reproductive tracts were done each time the implants were changed. Pregnancy rates were established by ultrasound examination of the reproductive tracts 44 days after AI.

Ninety-six days after AI the heifers were examined for the presence of their implants and they were examined per rectum for pregnancy. Two of the pregnant heifers were then selected at random and the implants were removed and pregnancy determined at the next implant removal/insertion time (20 days after implant removal).

At 273 days of gestation, the last set of implants were removed. The heifers were frequently observed for parturition after the last set of implants were removed. The control heifers were frequently observed for parturition beginning two week before the estimated calving date and until the last heifer had calved.

Total mass of norgestomet in implanted and non-implanted implants were determined using procedures described by Kesler et al. (11). Total content of norgestomet was determined on 6 non-implanted implants, on 6 implants left in situ for 39 days, and on 6 implants left in situ for

59 days. The implanted implants were from the heifers that maintained pregnancy for 273 days after AI. It has been well established that there is a burst release of steroids from matrix type silicone implants during the first two or three days after implantation followed by a relatively constant release (12 for review). Therefore, three of the non-pregnant ovariectomized heifers were implanted with two of the 15 mg norgestomet/silicone implants each for three days. Upon removal after three days *in situ* the mass of norgestomet remaining in the 6 implants was determined (11). Based on these data, mass of norgestomet release during the majority of the implantation periods (days 3 to 39 and days 39 to 59) was determined (11).

Qualitative data were analyzed by Chi-square analysis (13) and quantitative data were analyzed by analysis of variance (14).

RESULTS

It was revealed during post-surgery examination of the ovaries that the complete ovarian tissue was removed from all fifteen of the ovariectomized heifers. Three of the heifers did not have corpora lutea on the ovaries. Apparently these heifers did not ovulate or had luteal dysfunction (15). Either way, since there were no corpora lutea, these three heifers had no possibility of having viable embryos present at ovariectomy.

The pregnancy rates are reported in table 1. These pregnancy rates were the number of heifers pregnant at 44 days after AI divided by the number of heifers treated for synchronization. The overall pregnancy rate was 62% and there was no difference ($P > .25$) between control and ovariectomized/norgestomet treated heifers.

Three of the remaining 8 pregnant heifers maintained gestation for 273 days (the time that the last set of norgestomet implants were removed). Two heifers appeared to undergo embryo mortality. At the time of pregnancy detection one embryo was smaller than normal and did not have a heartbeat. Upon subsequent examination (65 days after AI) it was revealed that the pregnancy had been lost. The other heifer with embryo mortality was discovered open 96 days after AI. Overall, one control heifer (4%) and two ovariectomized/norgestomet treated heifers (25%) had embryonic mortality between 44 and 96 days of gestation. The embryonic mortality rate tended ($P = .07$) to be higher for the ovariectomized/norgestomet implanted heifers than for the control heifers.

In two of the pregnant heifers the norgestomet/silicone implants were removed 96 days after AI. Subsequent examination of these heifers 116 days after AI revealed that the pregnancies were aborted. In another heifer, one of the two implants was lost after the second implantation (65 to 96 days of gestation). Upon examination of the reproductive tract on day 96 it was revealed that the pregnancy had been lost.

Two hundred and seventy-three days after AI the last set of norgestomet/silicone implants were removed from the pregnant heifers. These three heifers calved 27 to 52 hours (mean = 41 hours) after implant removal. Although the gestation period of these three heifers was of similar ($P > .10$) duration to the control heifers, the ovariectomized/norgestomet implanted heifers calved an

average of 8 days earlier than the control heifers. The incidence of dystocia ($P < .05$) and retained fetal membranes ($P < .01$) was greater in the ovariectomized/norgestomet treated heifers than in the control heifers and calf survival was lower ($P < .01$) for the ovariectomized/norgestomet treated heifers than for the control heifers (table 1).

The implants were manufactured to have 15 mg of norgestomet and upon removal of norgestomet from new implants 15.84 mg of norgestomet was analytically detected. Recovery of norgestomet from the implants used in the heifers in this study allowed for determination of the amount of norgestomet released *in vivo*. These data demonstrated that the two implants released a total of 314 μg of norgestomet daily. The daily amount released per implant was 158 μg from days 3 to 39 and 155 μg from days 39 to 59.

DISCUSSION

Forty-four days after insemination (34 days after ovariectomy) 53% of the ovariectomized heifers were pregnant which is similar to untreated control heifers. If only the heifers that had corpora lutea at ovariectomy were considered, the pregnancy rate was 67%. Post-treatment norgestomet treatment of synchronized heifers has previously been demonstrated to have no detrimental effects on the pregnancy rate of heifers and cows (16, 17). In fact, post-insemination norgestomet treatment has been demonstrated to enhance the pregnancy rate in heifers (6) and synchronize the return estrus for non-pregnant heifers and cows (16, 17). In that study (16), however, the first service pregnancy rate for the untreated control heifers was lower than for control heifers in this study.

When implants were removed from two of the pregnant heifers 96 days after insemination, their pregnancies were lost. Removal of the implants 273 days after insemination resulted in parturition an average of 41 hours later. This interval is similar to the interval for the artificial induction of parturition with glucocorticoids and estradiol-17 β (3, 18, 19). Therefore, it appears that norgestomet maintained pregnancy in the ovariectomized heifers which is in general agreement with previous research that has shown that natural progesterone or a synthetic progestin, MGA, maintains pregnancy in ovariectomized heifers (2, 4, 5, 20, 21, 22).

The norgestomet implants used in this study released approximately 314 μg of norgestomet daily for the majority of time that the implants were *in situ*. This is far higher than the dosage required to suppress estrus (8, 9). Since the pregnancy in the heifer that lost one implant was lost, it is possible that the dosage of norgestomet required to maintain pregnancy is higher than the dosage required to suppress estrus as demonstrated for MGA (2). One implant would have released approximately 157 μg of norgestomet daily while the daily dose required to suppress estrus is approximately 140 μg (9). Even the approximately 314 μg dosage of norgestomet per day may have been low since there tended to be a higher percentage of ovariectomized/norgestomet treated heifers that underwent embryonic mortality than control heifers.

Butcher et al. (23) used 15 and 25 mg norgestomet implants (of similar size as used in this study) in an attempt to maintain the pregnancy of embryos transferred into the uterus of early postpartum cows with luteal dysfunction. The conclusion of Butcher et al. (23) was that 15 and 25 mg

implants were not sufficient to maintain pregnancy. There may be two reasons for the lack of success of Butcher et al (23). First, Butcher et al. (23) used only one 15 or one 25 mg norgestomet implant per cow whereas two 15 mg implants were used per heifer in this study. Based on the release of steroids from matrix type silicone implants, it would be expected that two 15 mg implants would release substantially more norgestomet than one 25 mg implant because of the greater implant surface area for diffusion (12). Second, heifers in this study had no ovarian tissue remaining whereas the cows used in the Butcher et al. (23) study were intact. Zimbelman and Smith (2) reported that 1 mg of MGA daily maintained pregnancy in 47% of the cows when both ovaries were removed, whereas 1 mg of MGA maintained gestation in none of the cows when one ovary without the corpus luteum remained. Likewise, McDonald et al. (20, 21) found that a higher dose of progesterone was required to maintain pregnancy in cows after removal of the corpus luteum than in ovariectomized cows.

The dosage of MGA required to maintain pregnancy in over 75% of the ovariectomized cows, a similar percentage to the percentage of heifers that maintained pregnancy in this study with norgestomet, was determined to be 4.0 mg by Zimbelman and Smith (2). Therefore, approximately 10 times the estrus suppression dosage of MGA was required to maintain pregnancy in ovariectomized cows (2) whereas norgestomet was as effective in maintaining pregnancy in ovariectomized heifers with only about 2.25 times the estrus suppression dosage (9). Similarly, 2 times the dosage of norgestomet needed to suppress estrus suppressed the pulsatile release of luteinizing hormone (LH) similar to midluteal phase concentrations of progesterone (24) whereas 3 times the dosage of MGA needed to suppress estrus (the highest dose tested) did not suppress the pulsatile release of LH (25).

In the absence of exogenous progestins, Chew et al. (3) demonstrated that after ovariectomy on day 218 some cows had partial recovery of progesterone and had low concentrations of progesterone in the plasma. It has been previously demonstrated that the minimal doses of exogenous progesterone to maintain pregnancy decreased progressively from 2.5 mg (per kg body weight per day) on day 30 of gestation to a zero requirement at days 195 and 210, and then increased gradually, thereafter, to greater than .55 mg at day 270 (5). Because of the data of Chew et al. (3), it may be assumed that there is an extraovarian source of progesterone by at least 215 days of gestation and later. Since ovariectomized cows that maintained pregnancy aborted after adrenalectomy (26) and since bovine placental extracts only have a minimal capability to synthesize progesterone (27), it may be hypothesized that the extraovarian source of progesterone is the adrenals.

Even when pregnancy was maintained in ovariectomized females, the events associated with parturition were abnormal as observed by other investigators (1, 3). Chew et al. (3) reported that the abnormal endocrine milieu in ovariectomized heifers led to abnormal parturition. Alternatively, however, the absence of undefined secretions by the ovarian tissue may be responsible for the increased incidence of abnormal parturitions. Preterm parturition that occurs after the artificial induction of parturition causes an increased incidence of retained fetal membranes (3, 18, 19) but the artificial induction of parturition within two weeks of term is generally not associated with an increased incidence of dystocia and calf mortality as observed for ovariectomized females.

The interval from norgestomet implant removal to parturition was shorter in this study than observed by Zimbelman and Smith (2) for MGA. In the study by Zimbelman and Smith (2) the interval from last day of MGA feeding to parturition was 7 to 15 days. This may suggest more rapid metabolism of norgestomet after implant removal than after the last oral administration of MGA.

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REFERENCES

- Ainsworth, L., and K.J. Ryan. 1967. Steroid hormone transformations by endocrine organs from pregnant mammals. II. Formation and metabolism of progesterone by bovine and sheep placental preparations in vitro. *Endocrinology* 81:1349.
- Bolte, K.A., H.A. Garverick, D.J. Kesler, B.N. Day, and E.C. Mather. 1977. Dexamethasone and estradiol benzoate induced parturition in dairy cattle. *Theriogenology* 8:45.
- Butcher, R.L., J.E. Reber, A.W. Lishman, K.F. Breuel, F.N. Schrick, J.C. Spitzer, and E.K. Inskeep. 1992. Maintenance of pregnancy in postpartum beef cows that have short-lived corpora lutea. *J. Anim. Sci.* 70:3831.
- Chew, B.P. R.E. Erb, J.F. Fessler, C.J. Callahan, and P.V. Malven. 1979. Effects of ovariectomy during pregnancy and of prematurely induced parturition on progesterone, estrogens, and calving traits. *J. Dairy. Sci.* 62:557.
- Darling, Lisa. 1993. *Veterinary Pharmaceuticals and Biologicals*. Veterinary Medicine Publishing Co., Lenexa, KS.
- Estergreen, V.L., O.L. Frost, W.R. Gomes, R.E. Erb, and J.F. Bullard. 1967. Effect of ovariectomy on pregnancy maintenance and parturition in dairy cows. *J. Dairy Sci.* 50:1293.
- Favero, R.J., D.B. Faulkner, and D.J. Kesler. 1993. Norgestomet implants synchronize estrus and enhance fertility in beef heifers subsequent to a timed artificial insemination. *J. Anim. Sci.* 71:2594.
- Favero, R.J., D.B. Faulkner, T.G. Nash, and D.J. Kesler. 1995. Effect of norgestomet treatment post-insemination on the calving rate of postpartum suckled beef cows. *J. Anim. Sci.* 73:3230.

- Gilbert, H.G., G.H. Phillipps, A.F. English, L. Stephenson, E.A. Wollett, C.E. Newall, K.J. Child. 1974. The progestational and anti-estrogenic activities of some novel 11 β -substituted steroids. *Steroids* 23:585.
- Hicks, C.R. 1964. *Fundamental Concepts in the Design of Experiments*. Holt, Rinehart and Winston, Inc., New York, NY.
- Johnson, K.R. and R.E. Erb. 1962. Maintenance of pregnancy in ovariectomized cattle with progestin compounds and their effects on progestin levels in the corpus luteum. *J. Dairy Sci.* 45:633.
- Kesler, D.J., R.C. Peterson, R.E. Erb, and C.J. Callahan. 1976. Concentrations of hormones in blood and milk during and after induction of parturition in beef cattle with dexamethasone and estradiol-17 β . *J. Anim. Sci.* 42:918.
- Kesler, D.J., R.G. Elmore, E.M. Brown, and H.A. Garverick. 1981. Gonadotropin releasing hormone treatment of dairy cows with ovarian cysts. I. Gross ovarian morphology and endocrinology. *Theriogenology* 16:207.
- Kesler, D.J., P.G. Weston, C.A. Pimentel, T.R. Troxel, D.L. Vincent, and J.E. Hixon. 1981. Diminution of the in vitro response to luteinizing hormone by corpora luteal induced by gonadotropin releasing hormone treatment of postpartum suckled beef cows. *J. Anim. Sci.* 53:749.
- Kesler, D.J. 1989. Novel approaches and applications of steroid hormone delivery via polydimethylsiloxane. In *Applied Bioactive Polymeric Materials* (Gebelein, C.G., and R.L. Dunn, eds.), Plenum Press, New York, NY.
- Kesler, D.J., R.J. Favero, and T.R. Troxel. 1995. A comparison of hydron and silicone implants in the bovine norgestomet and estradiol valerate estrus synchronization procedure. *Drug Development and Industrial Pharmacy* 21:475.
- Kojima, F.N., J.R. Chenualt, M.E. Wehrman, E.G. Bergfeld, A.S. Cupp, L.A. Werth, V. Mariscal, T. Sanchez, R.J. Kittok, and J.E. Kinder. 1995. Melengestrol acetate at greater doses than typically used for estrous synchrony in bovine females does not mimic endogenous progesterone in regulation of secretion of luteinizing hormone and 17 β -estradiol. *Biol. Reprod.* 52:455.
- Machado, R. and D.J. Kesler. 1996. The efficacy of norethindrone acetate and norgestomet implants in suppressing estrus in beef heifers. *Drug Development and Industrial Pharmacy* (In Press).
- McDonald, L.E., R.E. Nichols, and S.H. McNutt. 1952. Studies on corpus luteum ablation and progesterone replacement therapy during pregnancy in the cow. *Am. J. Vet. Res.* 13:446.

- McDonald, L.E., S.H. McNutt, and R.E. Nichols. 1953. On the essentiality of the bovine corpus luteum of pregnancy. *Am. J. Vet. Res.* 14:539.
- Sanchez, T., M.E. Wehrman, F.N. Kojima, A.S. Cupp, E.G. Bergfeld, K.E. Peters, V. Mariscal, R.J. Kittok, and J.E. Kinder. 1995. Dosage of the synthetic progestin, norgestomet, influences luteinizing hormone pulse frequency and endogenous secretion of 17 β -estradiol in heifers. *Biol. Reprod.* 52:464.
- Steel, R.E.D. and J.H. Torrie. 1980. *Principles and Procedures of Statistics.* McGraw-Hill, New York, NY.
- Tanabe, T.Y. 1966. Essentiality of the corpus luteum for maintenance of pregnancy in dairy cows. *J. Dairy Sci.* 49:731 (Abstr.).
- Tanabe, T.Y. 1966. Margin of safety of ovarian progesterone in maintenance of single and twin pregnancies in dairy cattle. *J. Anim. Sci.* 25:931 (Abstr.).
- Wendorf, G.L., and N.L. First. 1977. Role of bovine adrenals in pregnancy maintenance. *J. Anim. Sci.* 45(Suppl. 1):218 (Abstr.).
- Wishart, D.F. 1972. Identification of steroids of high activity for control of the oestrous cycle in the dairy heifer. *J. Reprod. Fertil.* 30:333.
- Zimbelman, R.G. and L.W. Smith. 1966. Maintenance of pregnancy in ovariectomized heifers with melengestrol acetate. *J. Anim. Sci.* 25:207.

Table 1. Pregnancy rate and the maintenance of pregnancy by control and ovariectomized/norgestomet implanted heifers.

	Control	Ovariectomized/ Norgestomet Implanted
Initial number	40	15
Number pregnant ^a	26 ^g (65 %)	8 ^g (53 %)
Embryonic mortality ^b	1 (4 %)	2 ^c (25 %)
Implants removed-day 96	--	2 ^d
Implant/Pregnancy loss	--	1 ^e
Calved	25	3
Dystocia	3 ^h (12 %)	2 ⁱ (67 %)
Retained fetal membranes	0 ^j (0 %)	2 ^k (67 %)
Calf survival	25 ^j (100 %)	1 ^k (33 %)
Mean gestation period ^f	283 ± 11 ^g	275 ± 00 ^g

^aPregnancy rates were determined by ultrasound examination of the reproductive tract at 44 days after AI.

^bEmbryonic mortality was defined as pregnancies lost for no apparent reason from the time of pregnancy detection (44 days after AI) day 96.

^cTends to differ ($P = .07$) from control heifers.

^dImplants were removed from these two heifers 96 days after AI. Both heifers were diagnosed open 20 days later.

^eOne of the two implants was lost 65 to 96 days after AI. Upon examination of the reproductive tract 96 days after AI the heifer was diagnosed open.

^fMean ± range.

^gNo differences ($P > .10$) were detected between groups.

^{h,i}Values with different superscripts differ ($P < .05$).

^{j,k}Values with different superscripts differ ($P < .01$).

EFFECT OF PROSTAGLANDIN $F_{2\alpha}$ TREATMENT BEFORE NORGESTOMET AND ESTRADIOL VALERATE TREATMENT ON REGRESSION, FORMATION, AND FUNCTION OF CORPORA LUTEA IN BEEF HEIFERS

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SUMMARY

Two experiments were conducted to determine if corpus luteum regression, formation, and function were associated with the decreased calving rate observed in beef females administered $PGF_{2\alpha}$ five days before Syncro-Mate B (SMB) treatment. Exp. 1 included 31 beef heifers 11 to 13 months old and Exp. 2 included 31 beef heifers 19 to 21 months old. Heifers were randomly assigned to one of two groups (control and $PGF_{2\alpha}$ five days before SMB treatment). Heifers were bled 10 d before $PGF_{2\alpha}$ treatment, immediately before $PGF_{2\alpha}$ and SMB treatments, at the time of implant removal, and twice weekly after implant removal. Heifers in Exp. 2 were observed twice daily for estrus for five days after $PGF_{2\alpha}$ treatment and for 3 days after norgestomet implant removal. Based on the blood samples collected before SMB treatment, 15 heifers in Exp. 1 and all heifers in Exp. 2 were with estrous cycles. All heifers in Exp. 1 had progesterone concentrations < 0.5 ng/mL two days after implant removal. However, progesterone concentrations during the luteal phase in control heifers with estrous cycles were higher ($P < 0.05$) than in $PGF_{2\alpha}$ treated heifers with estrous cycles and in heifers previously without estrous cycles. In Exp. 2, based on estrus and progesterone concentrations, heifers were also classified as metestrus or diestrus at the time of SMB treatment and the data were analyzed as a 2 X 2 factorial with treatment (control or $PGF_{2\alpha}$) and stage of the cycle (metestrus and diestrus) as main effects. More metestrus heifers (40%) had progesterone concentrations > 1.0 ng/mL two days after implant removal than diestrus heifers (0%). In addition, progesterone concentrations during the luteal phase in metestrus heifers were lower ($P < 0.05$) than in diestrus heifers. $PGF_{2\alpha}$ treatment had no effect ($P > 0.25$) on the number of heifers with > 1.0 ng/mL progesterone two days after implant removal and progesterone concentrations during the luteal phase. There were no treatment by stage of the estrous cycle interactions. In summary, the administration of $PGF_{2\alpha}$ five days before SMB decreased calving rate by causing more heifers to be metestrus at SMB treatment. Fewer metestrus heifers (than diestrus heifers) were synchronized (with < 1.0 ng/mL of progesterone two days after implant removal) to SMB treatment and those synchronized had lower progesterone concentrations during the luteal phase.

INTRODUCTION

Estrus synchronization programs can be separated into two categories: luteolytic agents or combinations of progestins and luteolytic/anti-luteotropic agents. Programs using luteolytic agents (prostaglandin $F_{2\alpha}$; $PGF_{2\alpha}$) hasten estrus in females with mature corpora lutea (day 5 or greater of the estrous cycle; Lauderdale et al., 1974). The major problem with $PGF_{2\alpha}$ is the variability associated with the interval from treatment to estrus (Odde, 1990).

Programs utilizing progestins and luteolytic/anti-luteotropic agents, such as Syncro-Mate B® (SMB) which contains norgestomet and estradiol valerate, have more predictable intervals from progestin withdrawal to estrus allowing for a single timed artificial insemination (Hixon et al., 1981; Odde, 1990; Kesler and Favero, 1996). Pregnancy rates of bovine females synchronized with SMB, however, have been variable (Kesler and Favero, 1996).

Kesler et al. (1996) demonstrated that the administration of $\text{PGF}_{2\alpha}$ five days before SMB treatment decreased the calving rate of beef females because more $\text{PGF}_{2\alpha}$ treated females were in the first half of the estrous cycle when SMB was administered. Although this differs from data of Brink and Kiracofe (1988) where they observed the opposite, other data (Pratt et al., 1991; Fanning et al., 1992; Burns et al., 1993) support the data of Kesler et al. (1996). These experiments were conducted to determine if corpus luteum regression, formation, and function were associated with the decreased calving rate observed in beef females administered $\text{PGF}_{2\alpha}$ five days before SMB treatment.

MATERIALS AND METHODS

Thirty-one Angus heifers that were 11 to 13 months old and 31 Angus heifers that were 19 to 21 months old at the University of Illinois Beef Unit were used in experiments 1 and 2, respectively. Heifers were fed a total mixed diet balanced to meet or exceed all NRC (1996) requirements. Heifers were bled on days -27, -16, and -11 and all heifers were administered SMB on d -11. The SMB procedure consisted of an intramuscular injection of norgestomet (3.0 mg) and estradiol valerate (5.0 mg) in sesame oil and benzyl alcohol and an ear implant containing 6.0 mg of norgestomet. The implant was subcutaneously inserted into the convex surface of the ear and left in situ for 9 days. Five days before SMB treatment (day -16) heifers were randomly assigned to one of two groups. In Exp. 1, 16 of the heifers were administered $\text{PGF}_{2\alpha}$ (25 mg of Lutalyse®) on day -16. The other 15 received no treatment and served as controls. In Exp. 2, 18 of the heifers were administered $\text{PGF}_{2\alpha}$ (25 mg of Lutalyse®) on day -16 while the other 13 received no treatment and served as controls. Additional blood samples were collected immediately before implant removal, 2 days after implant removal (day 0) and on days 3, 7, and 14. Heifers in Exp. 1 were also bled on days 17 and 21. Heifers in Exp. 2 were also bled on day 10 (Figure 1). Heifers in Exp. 2 were observed twice daily for estrus for 5 days after $\text{PGF}_{2\alpha}$ treatment and for 3 days after implant removal. Heifers were considered in estrus if they stood to be mounted. Heifers in estrus > 60 hours after implant removal were considered delayed (for a 48-54 hour timed insemination).

Blood was collected via jugular venipuncture into syringes using 18 g needles 3.81 cm long. After collection the blood was immediately placed in an ice water bath and was held there until centrifugation which was done within 6 h after collection (Wiseman et al., 1983). Serum was harvested by centrifugation at 2,000 x g for 15 minutes at 4° C. Serum samples were individually stored in 1 mL vials at - 20° C until assayed. Progesterone concentrations were determined by a validated ELISA (Kesler et al., 1990). Heifers were classified with or without estrous cycles based on three blood samples collected before SMB treatment (day -27, -16, and -11) as previously described (Kesler et al., 1996). Ovulation and the short estrous cycles were identified

by progesterone concentrations on days 0 to 21 (days 0 to 14 in Exp. 2) as described by Kesler et al. (1981).

Data (incidence of heifers that did not ovulate, had short luteal phases, had progesterone concentrations > 1.0 ng/mL at implant removal and two days after implant removal, and estrus) in Exp. 1 were analyzed by analysis of variance (Steel and Torrie, 1980). Based on estrus and progesterone concentrations after the time of $\text{PGF}_{2\alpha}$ treatment, heifers in Exp. 2 were classified as metestrus or diestrus. Metestrus heifers were detected in estrus during the interval between $\text{PGF}_{2\alpha}$ and SMB treatments and had progesterone concentrations < 0.5 ng/mL at SMB treatment. Diestrus heifers were not in estrus during the interval between the time of $\text{PGF}_{2\alpha}$ and SMB treatments and had > 1.0 ng/mL of progesterone at SMB treatment. Data (incidence of heifers that did not ovulate, had short luteal phases, had progesterone concentrations > 1.0 ng/mL at implant removal and two days after implant removal, and estrus) in Exp. 2 were analyzed as a 2×2 factorial design with $\text{PGF}_{2\alpha}$ (control and treated) and stage of the cycle (metestrus and diestrus) as main effects (Steel and Torrie, 1980). Progesterone concentrations on days 0 to 21 (0 to 14 in Exp. 2) were analyzed by two methods: split plot analysis of variance (Gill and Hafs, 1971) and area under the response curve. The area under the response curve was determined mathematically and then analyzed by analysis of variance (Steel and Torrie, 1980). Only heifers that had luteal phases of normal duration were included in the analysis. In Exp. 1, heifers without estrous cycles (control and $\text{PGF}_{2\alpha}$ treated heifers combined) were also included in the analysis. In Exp. 2, analysis was done by excluding and including the heifers with progesterone concentrations > 1.0 ng/mL two days after implant removal. Results of both analysis (split plot analysis of variance and area under the response curve) agreed, however, the split plot analysis also provided information on the treatment by day interaction.

RESULTS

In Exp. 1, 75% of the heifers without estrous cycles either did not ovulate or had short luteal phases after norgestomet implant removal (Table 1). Although two (22%) of the $\text{PGF}_{2\alpha}$ treated heifers with estrous cycles had progesterone concentrations > 1.0 ng/mL (1.48 and 2.35 ng/mL; $1.92 \pm .44$ ng/mL) at the time of implant removal, all heifers had progesterone concentrations < 0.5 ng/mL two d after implant removal (Table 1). Progesterone concentrations during the luteal phase for heifers that had luteal phases of normal duration are illustrated in Figure 2. Progesterone concentrations were greater ($P < .05$) for control heifers with estrous cycles than for $\text{PGF}_{2\alpha}$ treated heifers with estrous cycles and heifers previously without estrous cycles.

In Exp. 2 all heifers were with estrous cycles. Administering $\text{PGF}_{2\alpha}$ 5 d before SMB treatment affected only the incidence of estrus after norgestomet implant removal (Table 2). More ($P < 0.01$) $\text{PGF}_{2\alpha}$ treated (5 d before SMB treatment) heifers were in estrus the 3 d after norgestomet implant removal than control heifers. Stage of the estrous cycle affected the incidence of heifers with progesterone concentrations > 1.0 ng/mL at implant removal and two d after implant removal (Table 2). More ($P < 0.01$) metestrus heifers had progesterone concentrations > 1.0 ng/mL at implant removal and two days after implant removal (1.26 - 3.65 ng/mL; $2.04 \pm .55$ ng/mL) than diestrus heifers. None of the treatment by stage of the estrous cycle interactions were significant ($P > 0.10$). Progesterone concentrations during the luteal phase were greater ($P <$

0.05) for diestrus heifers than for metestrus heifers (Figure 3), even when heifers with > 1.0 ng/mL progesterone two days after implant removal were excluded. Although progesterone concentrations in the metestrus heifers with > 1.0 ng/mL progesterone two days after implant removal increased, the increase was delayed by about 3 days (Figure 3).

DISCUSSION

We previously demonstrated that females administered SMB in the last half of the estrous cycle had higher pregnancy rates than females administered SMB in the first half of the estrous cycle (Kesler et al., 1996). This may be caused by a poor luteolysis of metestrus heifers to SMB treatment. Pratt et al. (1991), Fanning et al. (1992), and Burns et al. (1993) have demonstrated that SMB is ineffective in regressing corpora lutea in 42 to 48% of the metestrus (days 1 to 4 of the estrous cycle) females. Data in Exp. 2 agree with these researchers in that about 40% of the metestrus heifers had elevated progesterone concentrations two days after implant removal which is the time when the synchronized females are normally in estrus (Kesler and Favero, 1995). Rather than ineffective, however, SMB induced luteolysis may have been delayed because the data in Exp. 2 suggest that the metestrus heifers with progesterone concentrations > 1.0 ng/mL two days after implant removal had estrous cycles of less duration (approximately 15 to 18 days) than normal (Favero et al., 1993). Because corpora lutea lysed in all heifers in Exp. 1 and in all metestrus heifers in studies conducted by Kesler et al. (1984) and Kesler and Favero (1995), the ineffectiveness of SMB in inducing luteolysis in metestrus females is not consistent.

Progesterone secretion during the luteal phases of the $\text{PGF}_{2\alpha}$ treated heifers with estrous cycles was suppressed as compared to non- $\text{PGF}_{2\alpha}$ treated heifers with estrous cycles in Exp. 1. Although a $\text{PGF}_{2\alpha}$ treatment effect was not detected in Exp. 2, metestrus heifers had less progesterone secretion during the luteal phase than diestrus heifers. This suppression was apparent during the entire luteal phase (Figures 2 and 3). The suppressed progesterone secretion in Exp. 1 was similar ($P > 0.25$) to heifers induced to have the first pubertal estrous cycle. Suppressed progesterone secretion by corpora lutea of normal duration during the first postpartum ovulation has been reported by Troxel et al. (1983). In that study, in addition to suppressed progesterone secretion, fertility was also reduced. Several publications have demonstrated that luteal phase progesterone concentrations in untreated cows are lower in cows that conceive and cows that don't conceive (Folman et al., 1973; Erb et al., 1976; Rosenberg et al., 1977). Further, it has been demonstrated that supplemental progestins during the luteal phase enhance the establishment of pregnancy to the previous insemination (Wiltbank et al., 1956; Johnson et al., 1958; Robinson et al., 1989; Favero et al., 1993). Collectively, these data may suggest that early embryo maintenance may be enhanced in females with higher progesterone concentrations.

CONCLUSION

$\text{PGF}_{2\alpha}$ five days before SMB treatment may decrease the pregnancy rate by causing more females to be in metestrus at SMB treatment. Metestrus females have a poor or delayed luteolysis to SMB treatment and metestrus females have lower luteal phase progesterone secretion. Although the data of this study provide insight as to why SMB administration 5 days after $\text{PGF}_{2\alpha}$ treatment depressed fertility, it is still unclear as to why Brink and Kiracofe (1988) observed opposite results

regarding fertility of females administered SMB during the first and last halves of the estrous cycle.

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REFERENCES

- Brink, J.T. and Kiracofe, G.H., 1988. Effect of estrous cycle stage at Syncro-Mate B treatment on conception and time to estrus in cattle. *Theriogenology* 29:513.
- Burns, P.D., Spitzer, J.C., Bridges, W.C., Henricks, D.M. and Plyler, B.B., 1993. Effects of metestrous administration of a norgestomet implant and injection of norgestomet and estradiol valerate on luteinizing hormone and development and function of corpora lutea in suckled beef cows. *J. Anim. Sci.* 71:983.
- Erb, R.E., Garverick, H.A., Randel, R.D., Brown, B.L. and Callahan, C.J., 1976. Profiles of reproductive hormones associated with fertile and nonfertile inseminations of dairy cows. *Theriogenology* 5:227.
- Fanning, M.D., Spitzer, J.C., Burns, G.L. and Plyler, B.B., 1992. Luteal function and reproductive response in suckled beef cows after metestrus administration of a norgestomet implant and injection of estradiol valerate with various dosages of injectable norgestomet. *J. Anim. Sci.* 70:1352.
- Favero, R.J., Faulkner, D.B. and Kesler, D.J., 1993. Norgestomet implants synchronize estrus and enhance fertility in beef heifers subsequent to a timed artificial insemination. *J. Anim. Sci.* 71:2594.
- Folman, Y., Rosenberg, M., Herz, Z. and Davidson, M., 1973. The relationship between plasma progesterone concentrations and conception in postpartum dairy cows maintained on two levels of nutrition. *J. Reprod. Fertil.* 34:267.
- Gill, J.L. and Hafs, H.D., 1971. Analysis of repeated measurements of animals. *J. Anim. Sci.* 33:331.
- Hixon, D.L., Kesler, D.J., Troxel, T.R., Vincent, D.L. and Wiseman, B.S., 1981. Reproductive hormone secretions and first service conception rate subsequent to ovulation control with Syncro-Mate B. *Theriogenology* 16:219.

- Johnson, K.R., Ross, R.H. and Fourt, D.L., 1958. Effect of progesterone administration on reproductive efficiency. *J. Anim. Sci.* 17:386.
- Kesler, D.J., Faulkner, D.B., Machado, R., Ireland, F.A. and Tjardes, K.E., 1996. Effect of prostaglandin $F_{2\alpha}$ administered before estrus synchronization with norgestomet and estradiol valerate on calving rates of beef cows. *J. Anim. Sci.* 74:2076.
- Kesler, D.J., Khazali, H. and Favero, R.J., 1990. Quantification of steroids via a polymer linked second antibody immunoassay: methods of linking anti-rabbit IgG to poly(styrene). In: *Progress in Biomedical Polymers*. Ed., C.G. Gebelin and R. Dunn. Plenum Publishing Co., New York, p. 157.
- Kesler, D.J., Weston, P.G., Pimentel, C.A., Troxel, T.R., Vincent, D.L. and Hixon, J.E., 1981. Diminution of the *in vitro* response to luteinizing hormone by corpora lutea induced by gonadotropin releasing hormone treatment of postpartum suckled beef cows. *J. Anim. Sci.* 53:749.
- Kesler, D.J. and Favero, R.J., 1995. Estrus synchronization in beef females with norgestomet and estradiol valerate. Part 1: mechanism of action. *Agri-Practice* 16:6.
- Kesler, D.J. and Favero, R.J., 1996. Estrus synchronization in beef females with norgestomet and estradiol valerate. Part 2: factors limiting and enhancing efficacy. *Agri-Practice* 17:12.
- Kesler, D.J., Favero, R.J., Ruoff, W.L., and Troxel, T.R., 1984. The effect of the stage of the estrous cycle on corpus luteum function of heifers treated with Syncro-Mate B. *Theriogenology* 21:243.
- Lauderdale, J.W., Sequin, B.E., Stellflug, J.N., Chenault, J.R., Thatcher, W.W., Vincent, C.K. and Loyancano, A.F., 1974. Fertility of cattle following $PGF_{2\alpha}$ injection. *J. Anim. Sci.* 38:964.
- NRC. 1996. *Nutrient Requirements of Beef Cattle*. National Academy Press, Washington, DC.
- Odde, K.B., 1990. A review of synchronization of estrus in postpartum cattle. *J. Anim. Sci.* 68:817.
- Pratt, S.L., Spitzer, J.C., Burns, G.L. and Plyler, B.B., 1991. Luteal function, estrous response and pregnancy rate after treatment with norgestomet and various dosages of estradiol valerate in suckled cows. *J. Anim. Sci.* 69:2721.
- Robinson, N.A., Leslie, K.E. and Walton, J.S., 1989. Effect of treatment with progesterone on pregnancy rate and plasma concentrations of progesterone in holstein cows. *J. Dairy Sci.* 72:202.

- Rosenberg, M., Herz, Z., Davidson, M. and Folman, Y., 1977. Seasonal variations in postpartum plasma progesterone levels and conception in primiparous and multiparous dairy cows. *J. Reprod. Fertil.* 51:363.
- Steel, R.G.D. and Torrie, J.H., 1980. *Principles and Procedures in Statistics.* McGraw-Hill Book Co., New York, NY.
- Troxel, T.R., Cmarik, G.F., Ott, R.S., Lock, T.F. and Kesler, D.J., 1983. The effect of method of GnRH administration and short-term calf removal on ovarian function and reproductive performance in postpartum suckled beef cows administered PGF₂ α for estrous synchronization. *Theriogenology* 20:417.
- Wiseman, B.S., Vincent, D.L., Thomford, P.J., Scheffrahn, N.S., Sargent, G.F. and Kesler, D.J., 1983. Changes in porcine, ovine, bovine and equine blood progesterone concentrations between collection and centrifugation. *Anim. Reprod. Sci.* 5:157.
- Wiltbank, J.N., Hawk, H.W., Kidder, H.E., Black, W.G., Ulberg, L.C. and Casida, L.E., 1956. Effect of progesterone therapy on embryo survival in cows of lowered fertility. *J. Dairy Sci.* 39:456.

Table 1. Number of heifers with and without estrous cycles that did not ovulate, had short luteal phases, had elevated progesterone concentrations at implant removal and two days after implant removal, and progesterone secretion by heifers with luteal phases of normal duration after PGF_{2α} and Syncro-Mate B treatments (Exp. 1).

	Without Estrous Cycles		P <
	Control	PGF _{2α} ^a	
Number	9	7	
Did not ovulate	5 (56%)	5 (71%)	
Short luteal phase	1 (11%)	1 (14%)	
Progesterone > 1.0 ng/mL:			
at implant removal	0 (0%)	0 (0%)	
at artificial insemination	0 (0%)	0 (0%)	
Luteal progesterone AUC ^b :			
mean	37.0	38.9	
standard error	3.3	---	
	With Estrous Cycles		P <
	Control	PGF _{2α} ^a	
Number	6	9	
Did not ovulate	1 (17%)	0 (0%)	
Short luteal phase	1 (17%)	1 (11%)	
Progesterone > 1.0 ng/mL:			
at implant removal	0 (0%)	2 (22%)	
at artificial insemination	0 (0%)	0 (0%)	
Luteal progesterone AUC ^b :			
mean	48.4	37.5	.05
standard error	2.7	3.1	

^aPGF_{2α} was administered 5 d before SMB treatment.

^bArea under the curve.

Table 2. Number of heifers with estrous cycles that did not ovulate, had short luteal phases, and had progesterone concentrations > 1.0 ng/mL at implant removal and two days after implant removal, and the progesterone secretion by heifers with luteal phases of normal duration after PGF_{2α} and Syncro-Mate B treatments (Exp. 2).

	Control	PGF _{2α} ^a	P <
Number	13	18	
Did not ovulate	0 (0%)	3 (17%)	
Short luteal phase	2 (15%)	0 (0%)	
Progesterone > 1.0 ng/mL:			
at implant removal	2 (15%)	6 (33%)	
2 d after implant removal	2 (15%)	2 (18%)	
Estrus	3 (23%)	13 (72%)	.01
Delayed estrus ^b	2 (15%)	3 (17%)	
Luteal progesterone AUC ^c :			
mean	50.1	41.9	
standard error	4.6	3.4	
	Metestrus ^d	Diestrus ^d	P <
Number	10	21	
Did not ovulate	2 (20%)	1 (5%)	
Short luteal phase	0 (0%)	2 (10%)	
Progesterone > 1.0 ng/mL:			
at implant removal	6 (60%)	2 (10%)	.01
at artificial insemination	4 (40%)	0 (0%)	.01
Estrus	5 (50%)	11 (52%)	
Delayed estrus ^b	2 (20%)	3 (14%)	
Luteal progesterone AUC ^c :			
mean	35.2 (36.6) ^e	49.9	.05 ^f
standard error	1.1 (1.4) ^e	3.6	

^aPGF_{2α} was administered 5 d before SMB treatment.

^bEstrus occurred > 60 h after implant removal.

^cArea under the curve.

^dHeifers were classified as metestrus if estrus was detected 1 to 4 d before SMB treatment.

^eMetestrus heifers with < 1.0 ng/mL two d after implant removal (n = 4).

^fBoth when heifers with > 1.0 ng/mL were included and excluded.

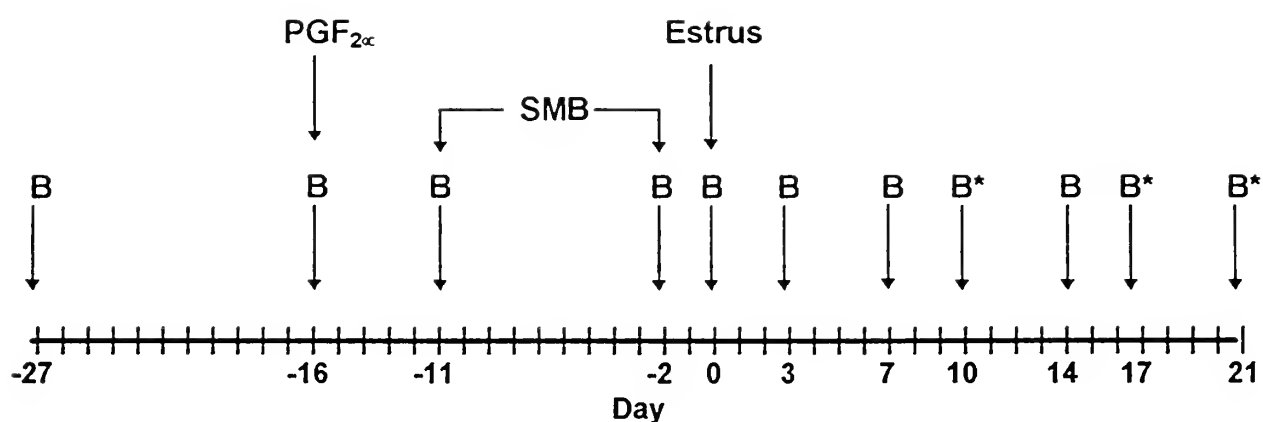


Figure 1. The schedule of treatments and blood collections. B refers to the times of blood collection. Heifers in Exp. 1 were not bled on day 10 and heifers in Exp. 2 were not bled on days 17 and 21 (B*).

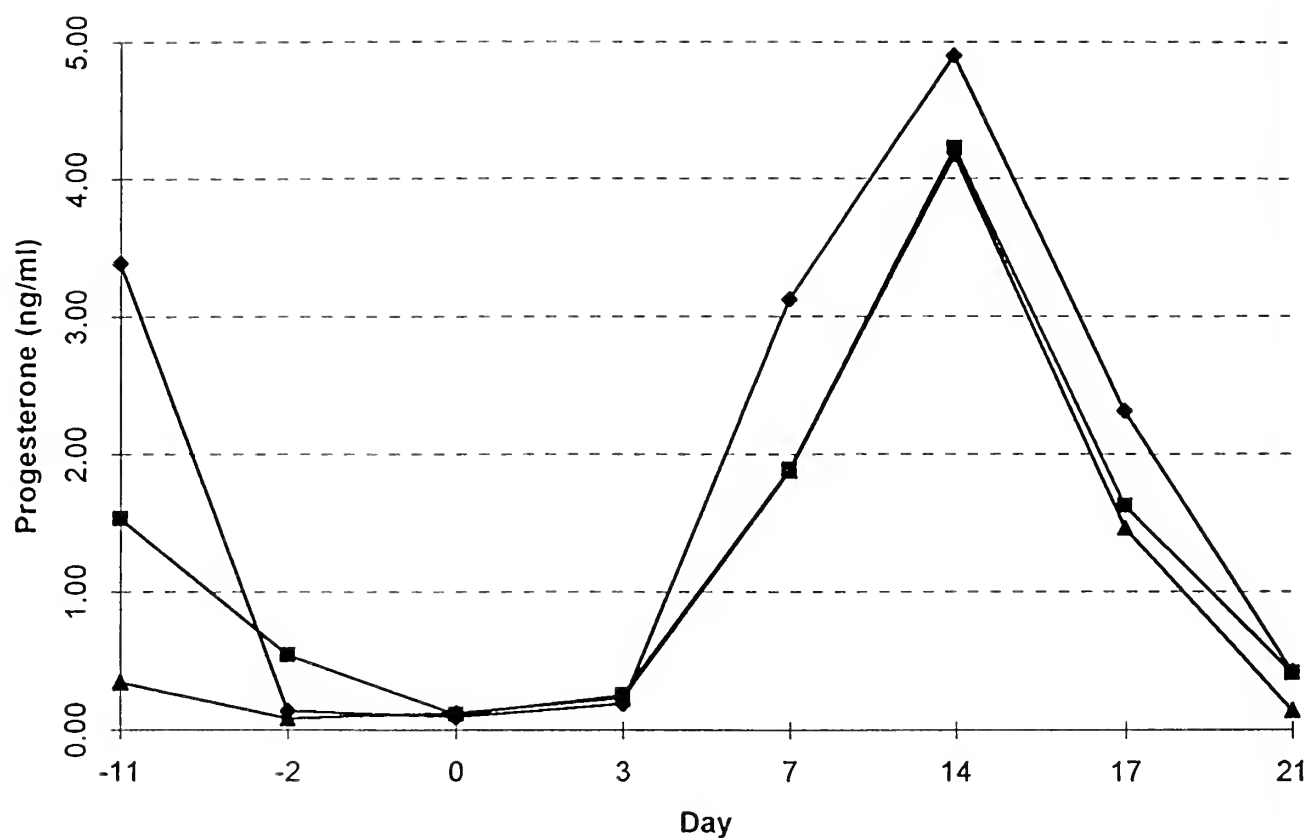


Figure 2. Luteal phase progesterone concentrations (ng/mL) of heifers previously without estrous cycles (triangles; $n = 4$) and heifers with estrous cycles after no treatment (diamonds; $n = 4$) or prostaglandin $F_{2\alpha}$ treatment (squares; $n = 8$).

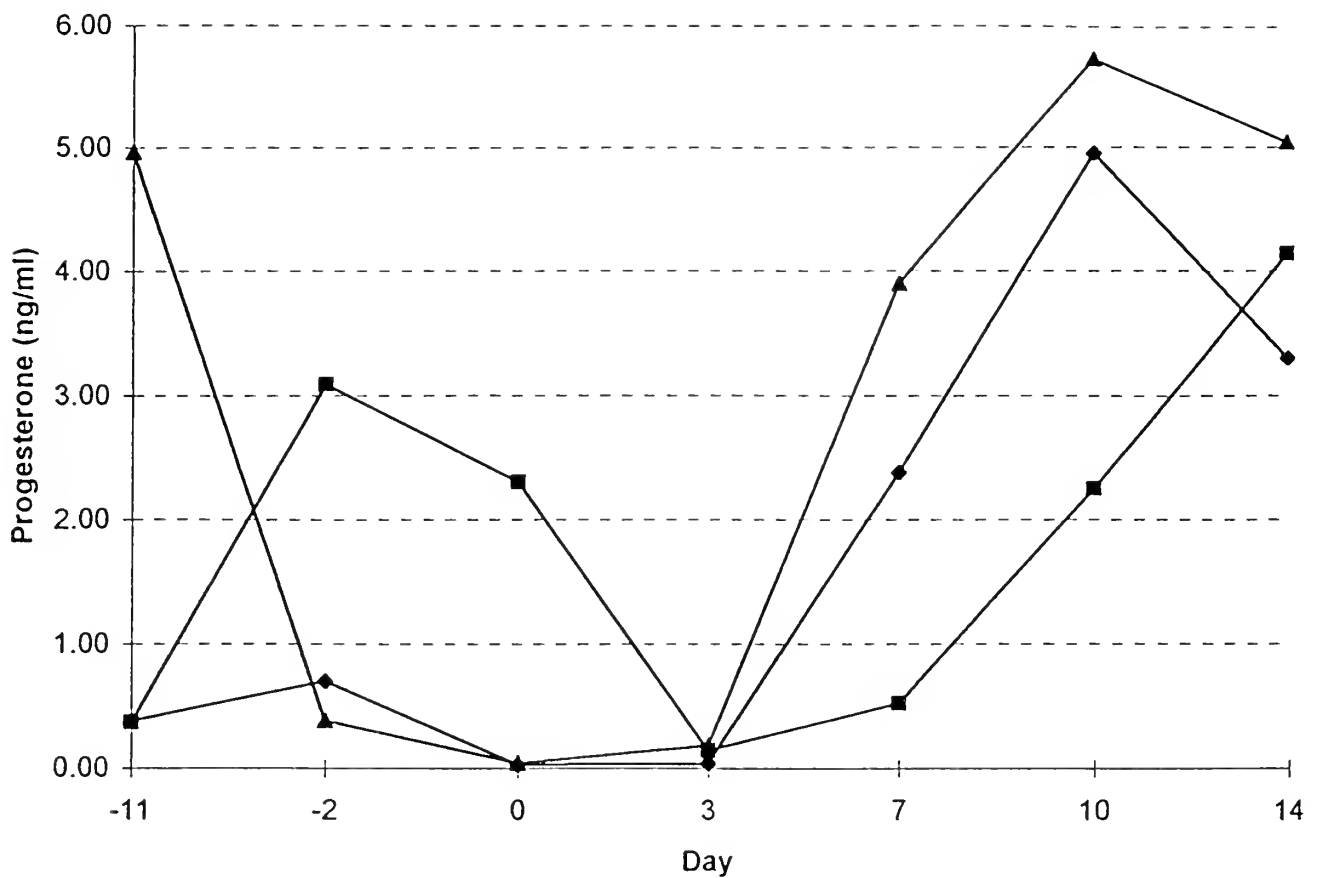


Figure 3. Luteal phase progesterone concentrations (ng/mL) in diestrus heifers (diamonds; $n = 18$), metestrus heifers with progesterone concentrations > 1.0 ng/mL two d after implant removal (squares; $n = 4$), and metestrus heifers with progesterone concentrations < 1.0 ng/mL two d after implant removal (diamonds; $n = 4$).

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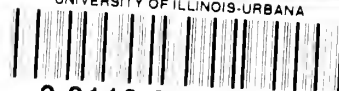
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